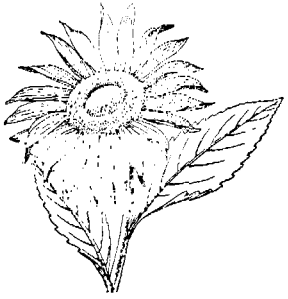
DECEMBER, 1932 BULLETIN 263

AGRICULTURAL EXPERIMENT STATION

KANSAS STATE COLLEGE OF AGRICULTURE
AND APPLIED SCIENCE

MANHATTAN, KANSAS

THE CODLING MOTH IN SOUTHERN KANSAS AND RECOMMENDATIONS FOR ITS CONTROL



PRINTED BY KANSAS STATE PRINTING PLANT
B. P. WALKER, STATE PRINTER
TOPEKA 1933
14-6164

SUMMARY

1. Because of the heavy infestation by the codling moth in the Arkansas river valley of southern Kansas, a considerably different spray schedule and supplementary control of program are required than elswhere in the country.

2. The codling moth ordinarily has three generations in this section. Life-history studies show that the first adults may be expected any time after April 15, the first eggs between May 5 and 15, and first-brood larvae from May 12 until late in June or early in July. First-brood adults may be expected any time after June 10, with the peak of emergence about July 1 to 10. The peak of second-brood adults may be looked for from August 10 to 20, and the peak of third-brood eggs about September 1. Practically all the larvae of the third brood hibernate, a very small number occasionally transforming to produce a small fourth brood of larvae all of which hibernate.

3. The most effective spray program against the codling moth has been found to be the use of acid lead arsenate at the rate of 2 pounds to 50 gallons of water, applied at the average rate of from 18 to 30 gallons per tree per spray, according to tree size, in seven sprays.

4. These sprays should consist of a calyx or petal-fall spray; four sprays applied to control the first brood, approximately at two-week intervals after the calyx, the first coinciding in time with the first blotch spray; two sprays applied during July and August to control second-brood larvae; and, in especially bad years where control of early broods has been unsatisfactory, a late spray about August 15 to 20 to control the third-brood larvae.

5. Supplementary measures, such as the use of chemical bands, proper pruning, cultivation, and packing-house and lug-box sanitation, are valuable aide in reducing the numbers of larvae that succeed in transforming into adults.

6. The most effective natural control seems to be the action of birds during the winter, the downy woodpecker being the primary species involved. Disease and parasites exercise but limited control, whereas birds in normal winters reduce the carry-over to a small percentage of the number entering the winter. Mild winters are likely to be followed by severe infestations, due to failure of these natural agencies to reduce the population sufficiently.

7. Actual comparison in 1929 showed the cost of the recommended spray procedure to be approximately $2.50 per tree per season, as against approximately 75 cents per tree per season under the present commercial practice. The income under average conditions of set and market, with trees mature and in good bearing, will be approximately $7.28 per tree by the recommended method and $4 per tree by the usual method. Increased income by the recommended method above spray cost's amounts to approximately $1.50 per tree, representing its financial advantage in average years over the usual method in use.

8. A spray calendar for apples in the Arkansas river valley of Kansas is included.

9. The spray material recommended is poisonous and, before consumption or marketing, the fruit should be washed or cleaned

TABLE OF CONTENTS

THE CODLING MOTH IN SOUTHERN KANSAS AND RECOMMENDATIONS FOR ITS CONTROL[1]

Paul M. Gilmer[2] and Ralph L. Parker

This bulletin summarizes the results of six years' cooperative investigation of the codling moth in the Arkansas river valley of southern Kansas, carried on by the Bureau of Entomology of the United States Department of Agriculture and the Kansas Agricultural Experiment Station.

THE ECONOMIC IMPORTANCE OF THE CODLING MOTH

The codling moth *(Carpocapsa pomonella* Linn.) is the most serious single pest of apples throughout the country. In southern Kansas it is, year after year, the limiting factor in the production of fruit of commercial quality. Under the ordinary commercial spray practice the annual loss is, in this section, from 10 to 40 per cent of the crop set, the fruit being little better than cider quality, with additional losses due to blemishes caused by worms before being killed by the spray. In many parts of the southern Kansas district good bearing orchards have been permitted to die and others have been pulled because the ravages of this insect made commercial production of fruit at a profit almost impossible. These investigations, however as well as the experience of a few of the more successful growers have shown that the codling moth can be profitably controlled in this section.

DESCRIPTION OF THE CODLING MOTH

The codling moth, like all other moths and butterflies, passes through four distinct life stages—egg, larva (worm), pupa (chrysalis), and adult.

The adult is a small, grayish-brown, mottled insect about half an inch long. (Fig. 1.) As seen in the orchard at rest, the wings are held tightly to the body, giving it much the appearance of a short length of fruit spur. With the wings spread the female is about

Acknowledgment.—This opportunity is taken to acknowledge the assistance given by Howard Baker, H. G. Butler, and Edwin W. Howe, full-time assistants during the investigation; by Rowan Potter, Donald McRoberts, and Calvin Arnold, temporary field assistants; and by Mrs. Vivian E. Smith, who tabulated the data. Acknowledgment is also made of the assistance, advice, and timely criticism given constantly during the investigation by Prof. George A. Dean of the Department of Entomology, Prof. R. J. Barnett of the Department of Horticulture of the Kansas station. Much credit is also due certain orchardists of the valley for their faithful coöperation.

1. Contribution No. 401 from the Department of Entomology.

2. The senior author was associate entomologist, Division of Fruit and Shade Tree Insects, Bureau of Entomology, United States Department of Agriculture. He was in charge of the coöperative field station at Wichita, Kan., during the period of the investigation herein reported.

FIG. 1.—Adult codling moth enlarged (inset, natural size).

three-fourths of an inch wide, the male slightly less. The most conspicuous mark of identification is the dull, metallic bronzing that tips the ends of the forewings, giving the moth at rest the appearance of having a bronzy half-moon at the rear tip of the body. The

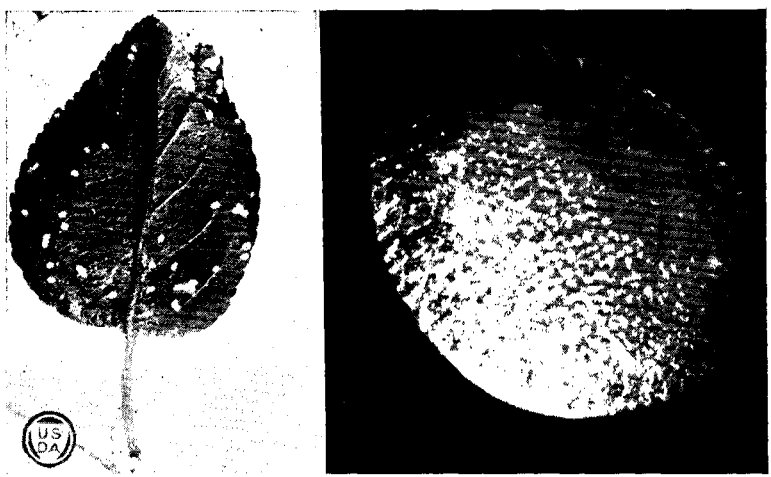


FIG. 2.—Codling moth eggs: Left, natural size on leaf; right, single egg much enlarged.

hind wings lack the chocolate shading of the forewings, being a brownish-gray unrelieved by any marking. The sexes are best distinguished by the slightly larger size and heavier body of the female.

The eggs (fig. 2) are pearly white, somewhat smaller in diameter than an ordinary brass pinhead, and very much flattened. Because of their small size they are quite inconspicuous, and are laid more or less at random upon the leaves, twigs, and fruit, although usually in the vicinity of fruit clusters.

In from a little over three days to as long as three weeks, depending upon weather conditions, these tiny eggs hatch into the larvae The worms are about one-eighth of an inch long, with rather prominent dark heads. They are whitish to orange in color, usually being of a creamy tint, but occasionally almost brown. When mature they are from one-half to three-quarters of an inch long, of a cream or pinkish color, with dark brown head and a small brownish shield on the back just behind the head.

When the mature larva (fig. 3) leaves the fruit, it crawls to dark and snug quarters where it spins a tight cocoon of grayish silk. According to whether it passes the winter in this cocoon or at once produces a new generation, this larva, now a prepupa, remains unchanged or changes after a day or more into a seed-like chrysalis or pupa. This pupa has clearly marked upon it the lines of the wings, legs, antennae etc., of the adult. In newly-transformed larvae the pupae are amber yellow. They gradually become a rich mahogany brown, and when about to emerge as adults are almost black.

After a varying length of time the pupa pushes itself out of the cocoon, the fore end of the pupa case splits open, and the adult emerges. Within a remarkably short time the insect dries, hardens, and is ready to take flight.

LIFE HISTORY OF THE CODLING MOTH IN SOUTHERN KANSAS

The codling moth in the Arkansas river valley of southern Kansas has, ordinarily, three distinct broods each season. In exceptional years, when conditions are unfavorable for the development of the insect, only two and a part of the third may develop. In other years, under conditions favorable to the insect, there may be a partial fourth brood.

It must be remembered that the insect is with us in some form or other throughout the year. Since the point of minimum abundance and the beginning of the fruit year coincide, the moth year may conveniently be considered as beginning approximately April 1. At this time the overwintered worms are still beneath the tree bark. Most of those that went into hibernation the previous fall have been killed by unfavorable weather, or by birds and other

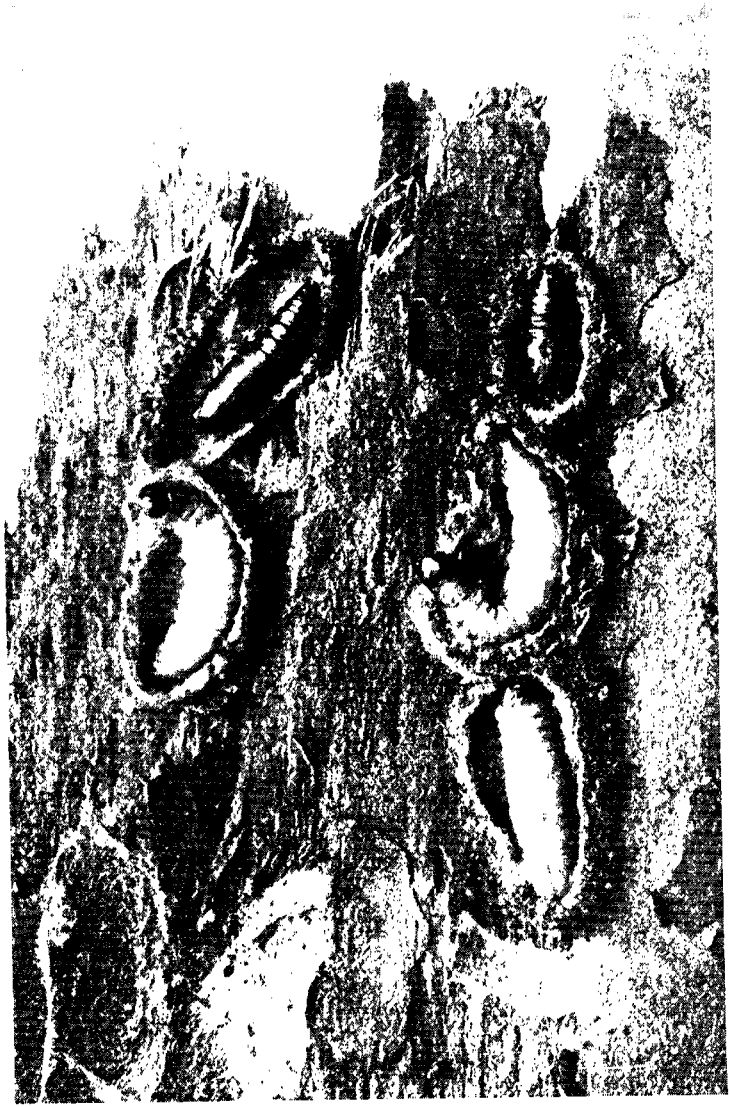


FIG. 3.—Larvæ and pupæ of codling moth in cocoons (twice natural size).

enemies, and the population is at its ebb as far as numbers of individuals are concerned.

During the warm days of early April those larva most exposed to the heat of the sun begin to prepare for pupation, and about the middle of the month begin to pupate in some numbers. In some years, however, the first pupae may appear as early as the last of March. April usually affords an abundance of warm days in spite of the colder evenings, so that about the last third of the month the first moths emerge. At this time most of the larvae are preparing to enter the pupal stage, and by the end of the month many of them have pupated. With normal favorable temperatures, adults appear in considerable numbers by May 1. Often the early part of May is cool and rainy, retarding pupal development so that the moths that appear previous to this time form a group by themselves which must be considered as separate from the rest of the spring brood.

About the middle of May the main spring brood begins to appear and continues to increase in abundance until the first week in June, when it begins to decrease, reaching an ebb about the middle of June. Moths from the hibernating larvae continue to appear, however, until well into July.

Usually about the end of the first week in May one or two warm nights occur with sundown temperatures well above 65° F. On these nights the small early group of moths will lay a considerable portion of their eggs, the resulting young worms appearing about May 18 to 20. Oviposition by the early members of the main spring brood will occur on the first warm nights after they emerge, so in average years the egg laying by this section of the spring brood will commence about May 15 and will continue in increasing numbers until a few nights after the peak of emergence. Since the late members of this spring brood and the moths coming from eggs of the earlier members of the same brood overlap late in June, it, may safely be considered that at no time between May 25 and the middle of September, when the nights are still fairly warm, and without rain, does a single night pass without oviposition.

The peak of hatch for the eggs laid by the spring brood (first brood eggs) usually commences soon after May 20 and reaches its maximum at about the end of the first week or 10 days in June. The worms enter fruit as soon as hatched and spend from 30 to 40 days as larva, depending upon the temperatures.

The earliest worms, those hatching about the middle of May, usually complete their feeding and begin to appear in small numbers outside the fruit during the last two weeks in June. They crawl down into some place where darkness and snug quarters offer them protection and there in a few days transform into pupae Before this small group has completed its transformation the main brood begins, so that from about the middle of June until late in July or early in August members of this brood may be found beneath the bark.

As pupation of these earliest individuals is completed about June 20, several days before the last spring-brood moths emerge, at this time begins that overlapping of broods which ultimately will completely conceal the sequence of broods. These early-emerging first-brood moths begin laying eggs a day or two after emerging, so appearance of the first worms of the second brood coincides with that of the last worms of the first brood. A large percentage of the first-brood moths begin to leave the fruit early in July and the peak of moth emergence is usually reached by the middle of the month. Because of the prevailing high temperatures, the eggs laid by these moths hatch in from four to six days, and the second-brood worms begin to enter fruit about July 20 or earlier. High temperatures continue as a rule throughout the month and development of the larva within the apples goes on much more rapidly than in the case of the first-brood larva. About three weeks later these larvae emerge from the fruit and begin to spin up, the peak of pupation coming about August 5 to 15. With the warm temperatures the pupal period is also short and the adults begin to appear late in July or early in August, the maximum appearance being about the middle of August.

The third-brood eggs appear within a day or so after the moths of the second brood emerge and because of the usual high temperatures at that time generally hatch within a few days (four to six) after being laid. The first third-brood larvae appear early in the month, overlapping the later members of that second brood. The main hatch usually occurs late in August, commencing about the 20th of the month and reaching a maximum about September 1. There is then a sharp decline and after September 15 the number of young worms appearing is rather small. The length of time over which this brood extends is considerably shorter than that of the second brood, probably because the later-emerging worms of the second brood hibernate instead of transforming.

When a fourth brood appears, it is usually due to especially favorable conditions throughout the season. It is restricted in numbers, usually occurs as a burst of late worms after September 15, and, except for a few individuals, rarely extends much over a week or 10 days. Under favorable weather conditions, however, small numbers of both the third brood and the fourth, when it occurs, may appear even fairly late in October.

The third-brood worms generally leave the fruit at about harvest time, completing their larval life within the fruit from the last of September to the middle of October. With early-maturing varieties such as Grimes Golden many of these worms are carried out of the orchard; in fact, such fruit is often attacked in storage, after grading, by larvae hatching from eggs laid on the fruit at picking time,

Practically all third-brood larva fail to pupate on leaving the fruit, but spin cocoons in suitable quarters for hibernation, furnishing the larger part of the spring-brood moths of the ensuing season.

METHODS OF CONTROLLING THE CODLING MOTH IN SOUTHERN KANSAS

Three methods are used in southern Kansas to control the codling moth. The most important of these is the use of poisonous sprays to kill the newly hatched larvæ before they enter the fruit. The second method is used as a supplement to the first, and consists in applying trap bands, either untreated or chemically treated, to the tree trunks some 6 to 8 inches above the ground, after the loose bark has been carefully scraped from the trees. This method is intended to capture the larvæ when they leave the fruit to pupate, thus preventing the increase in breeding population from brood to brood. The third method is a further extension of the banding method, combined with practices to increase the efficiency of the spray program. It involves orchard practices in pruning and cultivation that reduce the possible places of concealment for mature larvæ and expose them more readily to birds and other predators, while at the same time opening up and training the growth of the tree itself to permit easier access to fruit by the spray material.

SPRAYING FOR CODLING MOTH

The first line of defense against the codling moth is the spray placed upon the fruit and foliage to kill newly-hatched larvæ. The principle involved is to cover the fruit and foliage uniformly with sufficient poison to give the larvæ a fatal dose in the small bits that they cut from the fruit in entering. It cannot be too strongly emphasized that every orchard is a problem in itself and only through the experience of the operator working in that orchard can a spray schedule that will be satisfactory for it be designed. The professional helper from the Agricultural Experiment Station or elsewhere can only furnish the broad principles of control. The individual operator must use judgment and initiative details.

SPRAY MACHINERY.

The method commonly used is a wet spray of lead arsenate. The type of spray apparatus will vary with the acreage to be sprayed and with the topographical features of the orchard. There is probably little choice mechanically between any of the standard commercial spray machines. The possibility of getting repair parts and service quickly is the most important factor to be taken into consideration.

For a small orchard, from 1 to 5 acres, a good barrel sprayer with either a power or a good hand pump is fairly satisfactory unless the trees are old and large. With such a sprayer a pressure of 50 pounds and upward can be maintained and a reasonably good coverage secured. With this type of sprayer the use of spray rods rather than spray guns is recommended, since the rod enables the operator to reach the more inaccessible parts of the tree fairly readily in spite of lower pressure, even on days when there is consider-

able wind. Whatever type of barrel sprayer is used, a pressure of not less than 50 pounds should be maintained at all times, and the nozzle capacity ought to be such as to permit a complete coverage of all trees within from 4 to 6 days after spraying is begun.

Although it is reasonably effective, the large amount of labor necessitated by the use of the barrel type of sprayer is likely to lead to careless and inefficient spraying or to abandonment of spraying altogether. In southern Kansas, orchard blocks too small to make the maintenance of power sprayers profitable are likely to be a liability rather than an asset.

Where 10 or more acres of trees are grown, a high-pressure power outfit is economically feasible. The size of such outfits will vary with the acreage. For orchards covering from 10 to 15 acres a single- or double-cylinder pump outfit capable of carrying pressure up to 250 pounds and delivering at the nozzle 4 to 6 gallons per minute is reasonably satisfactory.

For the larger orchards larger machines are necessary. The standard machine for the section is the 200-gallon, three-cylinder pump outfit carrying pressures up to 350 pounds, with a delivery through two single-nozzle guns of approximately 8 to 12 gallons per minute.

For still larger blocks either two or more such machines are needed or the substitution of the large 300-gallon outfit, which, because of the saving of time in hauling in to refill, will permit the application of several hundred more gallons per day than will the smaller machines with the same crew. The weight of the large outfit, however, makes it hard to pull with two horses, especially if the ground is somewhat soft, as is likely to be the case in the early spring.

For the very large orchard either a number of 300-gallon machines or the giant 400- or 500-gallon three- or four-cylinder pump machines are used. The latter type practically requires tractor pulling, since the weight is too great for efficient horse management. Because of the high pressure (500 pounds) at which these machines operate, the delivery of spray material is rapid and the spraying can be accomplished considerably faster than with the smaller machines. The very large machines, because of the high initial cost and the necessity for tractors to pull them, are uneconomical except for the largest orchards. The 300-gallon machine is the sprayer commonly used in the larger orchards and, where a sufficient number of such units are operated, gives satisfactory results.

The three-pump, 200-gallon machine is the preferred machine locally for orchards of 60 acres or under, and should be used until at least four units are needed, when two of them may be replaced economically by a single 300-gallon machine. In such cases the retention of one of the old machines as reserve equipment is good economy, since it permits spraying to continue or to be hurried up at crucial times when breakdowns or shortness of available time makes added equipment desirable.

THE DELIVERY UNIT

The best type of nozzle is still largely a matter of opinion. Without doubt, where workmen can be obtained who will properly handle the old type of rod with "double-disc" type nozzles on a Y, far better and more uniform cover can be obtained than with any other equipment. The very serious objections to its use, however, have practically eliminated it from the commercial field. After a few hours the rod tires the workman so he becomes careless and fails to cover properly and uniformly. The fact that the labor is very fatiguing makes it difficult to retain good spray men if they can obtain work elsewhere with the less-fatiguing guns. Furthermore, the nozzle delivery with this type is much slower than with the guns, and the area that can be covered by a crew in a clay is considerably smaller.

The spray gun offers a variety of types for use. The simplest type is the single-nozzle gun with whirlpool nozzle, permitting adjustment of the spray from a broad cone to a narrow, far-reaching stream. It covers much more rapidly than the rod, is much less fatiguing to the operator, and much easier to handle in brushy trees. Since it has more driving force, it is possible to drive spray into even somewhat thick foliage, and to reach, in the tops of the trees, areas inaccessible to the rod. The force of the stream permits driving the spray to some distance even against a considerable wind. The weakness of the equipment is the fact that, from behind, the stream seems to cover a greater area than it actually does with efficiency and even experienced operators are likely to be deceived in covering the tops. The tendency to open the gun to the full and spray near and far branches alike is likely to lead to skips in the spray cover, and even to mechanical injury and russeting of fruit due to the violence with which the spray is applied. The higher the operating pressure the more likely is such injury to occur.

The double gun is similar to the single gun except that it carries two nozzles set slightly at an angle toward each other. The quantity of spray delivered is somewhat greater, and the area covered in a given time somewhat larger. On the other hand, the ability to throw spray to a distance is somewhat lessened, and the large cone of fine mist thrown out from the edges of the actual spray cone is very deceptive, causing the operator to misjudge the actual coverage unless he is thoroughly experienced with the gun and is more than commonly observant. Hence, skips and misses with this gun are more common than with the single-nozzle gun, and a more careful operator is required to do good work. Its chief advantage is the greater rapidity with which a given area can be covered.

One modification of the single-nozzle gun is found in the so-called angle gun, a spray gun 4 or 5 feet long with whirlpool nozzle and adjustable cone spray. Except for a tendency to develop mechanical trouble with the cut-off after considerable use, these guns are ideal for the ground sprayer, permitting him to reach into and up on the tree rapidly, and also to adjust the volume and delivery to meet either close or distant spraying.

A number of multiple nozzle guns have been invented, including the so-called spray-rake, which combine some of the better features of both the rod and the gun. The main objective in developing these types has been to increase the rapidity of cover and delivery without unduly decreasing the change of uniformity in distribution.

DUSTING FOR CODLING MOTH

Little or no dusting is done in the Arkansas river valley. In practice it has consistently failed to give adequate protection against codling moth and, except where the acreage is very large and a duster might serve as additional insurance when the time available for any application is short, dusting is not recommended for this section, either for protection against the codling moth or for applications of fungicides.

SPRAY MATERIALS RECOMMENDED AGAINST THE CODLING MOTH

During the six years the Wichita station has been in operation a large number of spray materials have been tested. These include various arsenicals in addition to lead arsenate; various organic poisons, such as nicotine, derris, and pyrethrum; oils alone and in combination; a large number of stomach poisons other than arsenicals, including some fluorine compounds; and various sticking and spreading agents. After six years of such work the station has returned unreservedly to the use of acid lead arsenate, the form in which lead arsenate is commonly sold, either with or without sticker or spreader, as the best standard practice. None of the other arsenicals showed any great promise, calcium arsenate, the best of those used, being about three-fourths as effective as the standard dosage of lead arsenate recommended.

A number of organic compounds showed some promise. Of these, pyrethrum, nicotine sulphate, and derris used with 1 per cent summer oil gave protection in the late sprays fairly comparable with that obtained by lead arsenate. When used throughout the season, however, they failed to give as efficient control. The oil used undoubtedly much increased their effectiveness, and were it not for the high cost they might be used with reasonable satisfaction for the last two sprays. To use these materials for the late sprays in an attempt to eliminate excessive spray residue without washing is, however, futile, because of the necessity of applying very heavy applications of arsenicals early in the season. Moreover, the cost of spraying with lead arsenate is less.

Summer oils in combination with the arsenical material showed some promise. They served as excellent spreaders and stickers, while at the same time the ovicidal effect of the oil reduced the number of live worms considerably, and the mechanical effect prevented stinging to a remarkable degree. Fruit sprayed with oil-lead arsenate showed only about one-third to one-fourth as many stings as the lead arsenate alone with approximately the same percentage of wormy fruit. The added cost and the increased difficulty in removing spray residue make one hesitate to recommend it for

general practice. The question of added profits from its use is still a debatable one for this section.

DOSAGE

A dosage of 1½ pounds of lead arsenate to 50 gallons of water did not give adequate control. An increase to 2 pounds to 50 gallons increased the degree of control remarkably, while 2½ pounds to 50 gallons gave still somewhat better results, but not sufficiently so to make its recommendation commercially desirable.

As a result; of the station's recommendation the standard practice is now to use the 2 to 50 dosage. For this district 1½ to 50 seems to approach the absolute minimum with which commercial control can be obtained under the most favorable circumstances, but it leaves no margin of safety to take up any failure to attain perfect cover.

MIXING

The usual practice is to mix the arsenate directly in the tank, sifting it upon the screen slowly as the water is poured in, with the engine and agitator in operation. This method seems to give good distribution and is simpler than the better practice of hand mixing with a small quantity of water before addition to the tank. If spreaders, such as casein or mineral oils, are used they should be added before the lead arsenate. Fish oil must not be used stronger than one-half pint to each 2 pounds of lead arsenate and should be previously emulsified to a creamy consistency with the arsenate and a small quantity (2 or 3 gallons) of water, and this emulsified oil-lead arsenate: then added to the tank. If care is not used with this sticker, the intake screens may become clogged with the oil, which, being a drying oil, sets in the meshes. After it is used the tank and pumps should be carefully washed and cleaned, else there is possibility of trouble due to setting of the oil about the ball valves, causing them to seat inaccurately and affecting pressure adversely.

QUANTITY OF SPRAY TO BE USED PER TREE

It has been found that a much larger quantity of spray per tree than is the usual practice for the district should be applied. For 20-year-old Winesaps in a fair state of growth and well pruned, from 15 to 20 gallons per tree per spray is recommended for adequate cover. Since these trees are somewhat smaller in growth habit than is true locally of many other varieties, such as Ben Davis, Grimes, Jonathan, and Stayman Winesap, it is estimated that for full-grown trees in an orchard of such mixed varieties between 20 and 30 gallons per tree per spray should be used on the average. With the average 200-gallon machine this would require a 2- to 2½-minute stop on each side of the tree, or four or five minutes per tree, to spray properly. To use this quantity without excessive drip requires careful spraying for the covering of the whole tree uniformly inside and out.

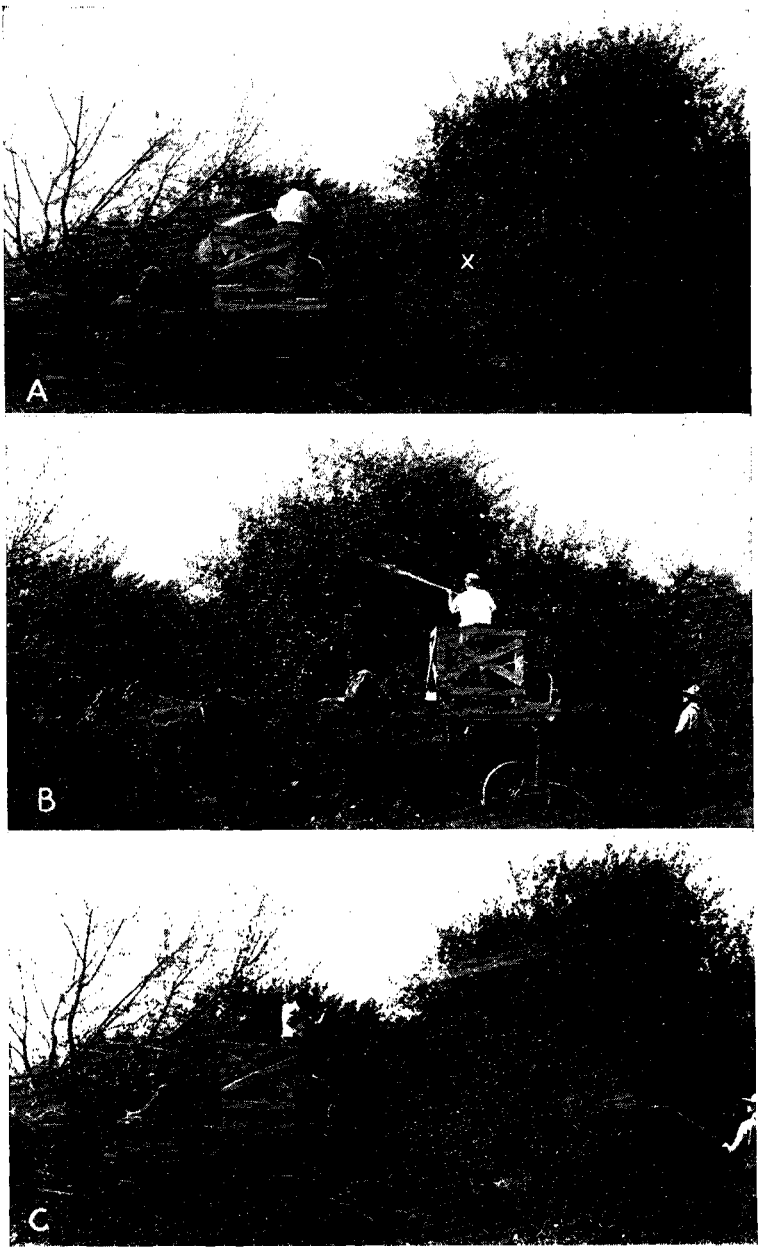


FIG. 4.—Spray rig and operators in three positions. (A) Position one for spraying the tree at the left. At "X" note the spray of the ground man coming through the leaves as he sprays the interior of the tree at the right from the trunk. (B) Position two. The ground man is coming around the near corner of the tree, the tower man is spraying through to cover the far side of the interior. (C) Position three. The tower man is covering the outgoing face of the tree at the right; the ground man is just ready to enter the tree to spray the interior.

SPRAY TECHNIC

On approaching the first tree, say on the east side from the north, the machine is stopped a short distance away and in such a position that the tower man can easily reach the whole north face of the tree. (Fig. 4, A.) Commencing at the top on the side opposite the rig (northwest corner) he begins to cover that portion of the tree farthest from him, spraying from the top down to about the level of the top of the spray wagon. He continues spraying toward himself, always spraying from the top down, until he reaches the corner nearest himself (northeast). He then commences to spray away from himself, from the top down as before, covering the side adjacent to the spray rig (east) from the incoming angle. When half this face is covered, the rig is brought to the second position (fig. 4, B), opposite the middle of the tree. The tower man now turns, spraying back to cover from the outgoing angle the part of the tree he has just covered from the incoming angle. He now sprays through the tree, covering the inside face of all fruit he can reach conveniently (west, north, and south faces) and again carefully sprays the top fruit, especially in the center section. Turning as he sprays, he now covers from the incoming angle the second half of the side adjacent to the spray rig, and the rig now pulls to the third position (fig. 4, C), which should bring it about into the first position for the second tree. Again the tower man turns back, covering from the outgoing angle the part of the tree he has just covered from the incoming angle, then sprays around on the south side of the tree, ending his spraying approximately opposite the corner at which he commenced, that is, at the southwest corner of the tree.

When the rig is moved into the second position the ground man starts to spray. He begins work on the northwest corner away from the spray machine, spraying from the upper section of his field (lower half of the tree) down, matching his work with that of the tower man and overlapping somewhat. A portion of his spray is directed into the upper section to cover the middle section fruit from beneath, as this cannot be accomplished readily by the tower man from his elevated position. The ground man should also direct his gun so that the under sides of the lower branches are covered with spray.

When the rig reaches the outgoing position the north face of the tree should have been covered. The ground man then enters the tree, takes a position close to the trunk and sprays out from the trunk in a circle. Here he also turns his gun upward to cover so far as possible the under side of the fruit in the center section of the tree, thus supplementing the work of the tower man in this section.

He now leaves the inner section of the tree and sprays around the west and south faces, completing his work about as the machine is moved forward to the second position at the second tree. This

tree he now enters at the corner immediately across (northwest corner) the row from where he has completed spray on the first tree.

The ground man is responsible for covering small areas that the tower man cannot reach because of wind, distance, screening branches, etc. The tower man should call his attention to these spots, which he should catch as best he can from the ground.

The rig is driven down the row to the end, returning according to the custom of the grower, either on the opposite side of the same row or on the corresponding side of the next row.

Because the strong prevailing winds in this district are generally southerly, it has been found best to spray both sides at the same time rather than to wait for a wind change that generally fails to come. Where this method of spraying is used, the spray rig should move either directly into or away from the wind as far as possible, since it is easier thus to cover the leeward face of the trees because the tree breaks the wind on this face. Some care must be used in spraying the faces at right angles to the wind, but by careful choice of position these faces can generally be fairly well covered.

It cannot be too strongly urged that the members of the spray crew be left permanently in their respective positions, rather than alternated every load as tower man and ground man. The fact that the ground man has a somewhat more strenuous job may be recognized by placing upon him responsibility as foreman of the crew at a slightly higher wage. This will do away with dissatisfaction over uneven distribution of labor, and at the same time permit each operator to become increasingly expert in his own job and the development of teamwork between them that will give a minimum of gun cut-offs.

It should be continuously impressed upon spray crews that adequacy of cover is desired above all, rather than rapidity in covering any given area, and that to cover too many trees with a spray load is even worse spray practice than to pour too much spray on any one tree.

SPRAY SCHEDULES

Good spraying consists in a combination of good spray practice, proper dosage, and proper timing of the schedule. No matter how well an orchard may be sprayed, if it is not sprayed at the proper time to supply the peak of hatch of worms with a plentiful dose of poison, good control is not possible. In calculating spray schedules the most important consideration is to keep an adequate supply of poison on the fruit when worms may be expected.

The earliest spray applied for the codling moth is the calyx or petal-fall spray. While at this time there are few, if any, worms in the orchard, this spray is necessary if the calyx or blossom end of the fruit is to receive an adequate dose of poison. This spray is of maximum importance. Failure to do a good job at this time cannot be remedied later because the calyx lobes will then be closed.

Proper timing of this spray consists in getting it on before these

calyx lobes close. Since in Kansas this spray is generally combined with lime-sulfur applied to control scab, too early application is likely to injure the delicate flower organs and cause sterility and lack of set. The poison in the blossom is also likely to poison the bees concerned in fertilizing the bloom; hence spraying at full bloom should be avoided.

The usual criterion for commencement of spray is when approximately three-fourths of the petals have fallen. (Fig. 5.) There is usually an interval of at least a week or 10 days between this time and the closure of the calyces. The application should be made as early in this interval as possible, as the young fruit develops rapidly

FIG. 5.—Apple blossoms from which petals have just fallen, showing the right time to apply the calyx spray. (Quaintance and Siegler.)

at this stage, tending to stand more erect and show less spread in the cluster, and it is more difficult to get the poison into the calyx cup as time goes on.

In occasional years unseasonably warm weather hastens growth so that but five or six days elapse between petal fall and calyx closure. Variety also makes some difference, the calyces closing much quicker on some varieties, as York Imperial, than they do on others, as Grimes Golden. In planning the order in which blocks are to be sprayed, these facts should be kept in mind, and those varieties that close early should be sprayed first.

In southern Kansas this spray is generally begun during the last few days in April and completed during the first week in May, but occasionally the petal fall will indicate that it should be commenced as early as April 20 or as late as May 10.

The calyx spray constitutes the base line from which the timing of the subsequent sprays is calculated. At this time the fruit and

leaves grow more rapidly and it is more difficult to maintain an adequate cover than at any subsequent time during the season. The second arsenical spray should ordinarily be applied with the first blotch spray, usually from 10 days to two weeks after the calyx spray. This, as a rule, is some time before commencement of the main brood hatch, but coincides closely with the commencement of hatch of eggs laid by the moths emerging late in April and the first week in May. This small group, while rather few in numbers, furnishes a good many moths for the second generation, since it is usually overlooked and many of these larvæ find conditions rather favorable for entrance owing to the out-growing of the cover applied with the calyx.

In the Arkansas valley district this spray is usually applied about May 12 to 15, and since many varieties should be sprayed for protection against blotch, the addition of the arsenical increases the total cost of spraying but little. The custom of compromising between this blotch spray and the spray for the main hatch should not be followed, as such spray comes too late to protect against this early burst of worms and adequately against blotch, and too early to give proper protection against the first portion of the main hatch.

The second cover spray should be directed against the commencement of the hatch of the main brood. Timing this spray is the most difficult task in making the schedule. The time of appearance of the hatch may vary by 10 days or more, while the rapid growth of the fruit makes a spray applied 10 days too early rather inadequate protection against entrance. High winds, causing excessive wind polish, heavy beating rains ordinarily common in this period, and rapid growth of the fruit all tend to reduce the effectiveness of cover at this time.

The criterion for determining the time of application has been a close observation of sundown temperatures throughout the middle half of May. The habit of the moth in ceasing oviposition at approximately 60° F. can be used as a marker. Most of the oviposition occurs between sundown and about 10 p. m., and when the temperature remains at 65° F. or above for two or three hours after sundown considerable laying of eggs may be expected. Gray days with the temperature above 65° F. will also induce considerable egg laying if conditions at night have been unfavorable for some time. The usual length of the egg stage under these conditions is between one and two weeks, averaging about 10 days, and is dependent almost wholly upon the temperature as indicated by the following tabulation:

Average temperature, degrees F.	Length of egg stage
60	16 days
65	10 days
70	9 days
75	7 days
80	5½ days
85	5 days
90	3¾ days

These are, of course, average temperatures for both day and night and not maximum or minimum recorded temperatures. As the average temperature for the latter half of May as recorded at the Wichita station of the United States Weather Bureau is approximately 68° to 69° F., approximately 10 days may be considered as the average length of time between oviposition and hatching. Therefore this spray ought to be completed between May 20 and 25, more commonly approaching the latter date.

Weather conditions after May 25 are such that oviposition occurs practically every night. From this date the schedule should be adjusted to one end only, to keep an adequate cover on the fruit at all times. Two more sprays are generally applied before the second-brood worms begin to appear in numbers, one about June 8 to 10, or about two weeks after completion of the second cover spray, and the second about June 25 to July 1. In a series of timing experiments two-week intervals between the second, third, and fourth cover sprays were found to be satisfactory.

For the second-brood larvæ two sprays are generally sufficient. These two sprays are ordinarily begun about July 15 to 18 and August 1 to 5.

Under this schedule, where well-timed spray has been properly applied, the late August spray against the third brood has been found to be unnecessary, the heavy accumulation of arsenic from the previous sprays giving adequate protection. Where control with the early sprays has been none too good, this late spray is indicated, and should be applied in average years beginning about August 15 to 20.

IT MUST BE REMEMBERED THAT THE EARLIER SPRAYS MAY VARY MARKEDLY IN TIMING, AND ONLY CAREFUL OBSERVATION IN THE INDIVIDUAL ORCHARD CAN DETERMINE THE PROPER DATE FOR COMMENCEMENT. The actual dates of commencing spray operations in 1930 and 1931 were as follows:

Spray	Date of Commencement of Spraying 1930	1931
Calyx	April 15	May 6
First cover	May 14	Not applied
Second cover	May 22	May 25
Third cover	June 10	June 17
Fourth cover	June 25	July 6
Fifth cover	July 16	July 24
Sixth cover	Aug. 8	Aug. 10

Control in these two blocks was quite comparable in the two years. The schedule for 1930, except for the exceptionally early calyx spray, is about average for the district. That for 1931, because of weather conditions, failed to get on the first cover, but was somewhat later throughout the season until the last spray in August, when the two practically coincided in timing.

A spray schedule for apples in this district is given in Table I.

TABLE I.—SPRAY SCHEDULE FOR APPLES IN SOUTHERN KANSAS.

SPRAY.	Material to apply and quantity per 100 gallons of water.	Purpose of spray: To control—	When to apply spray.
Dormant	Dormant oil, 3 gallons	San Jose scale	After December 1 and before March 15, when needed. Do not apply during freezing weather.
Pink	Liquid lime-sulfur, 3 gallons Lead arsenate, 3 pounds	Apple scab Canker worm	When buds show first pink. When canker worms are bad.
Calyx	Liquid lime-sulfur, 3 gallons Lead arsenate, 4 pounds	Apple scab Codling moth	After approximately three-fourths of petals have fallen.
Blotch (*a*)	Bordeaux mixture, 2:4:50 (*b*)	Blotch	Approximately two weeks after calyx spray.
First cover (*a*)	Lead arsenate, 4 pounds	Codling moth	Following first sundown temperature above 65°F. after May 5.
Second cover	Lead arsenate, 4 pounds	Codling moth	Following the first warm evening after May 15.
Third cover	Lead arsenate, 4 pounds Bordeaux mixture, 2:4:50	Codling moth Blotch	Two weeks after second cover and on varieties susceptible to blotch.
Fourth cover	Lead arsenate, 4 pounds Bordeaux mixture, 2:4:50	Codling moth Blotch	Two weeks after third cover and on varieties susceptible to blotch.
Fifth cover	Lead arsenate, 4 pounds	Codling moth	Three weeks after fourth cover spray.
Sixth cover	Lead arsenate, 4 pounds Bordeaux mixture, 2:4:50	Codling moth Sooty blotch	Approximately August 5 to 10. When weather is cool and damp.

(*a*) In about three years out of five these two sprays coincide in timing and may be put on together. Sundown temperatures preceding the spray will determine whether the arsenical should be used at the time of the blotch application or earlier or later.

(*b*) This means 2 pounds of copper sulphate (blue vitriol) and 4 pounds of fresh hydrated lime to each 50 gallons of water.

SUPPLEMENTARY MEASURES OF CONTROL

BANDING

In addition to the defense afforded by the spray program, there are a number of other means of reducing the worm population during the season. Probably the best known of these is the use of bands about the tree trunks for trapping larvae as they seek quarters for spinning up before pupation. The usual method is to remove, as far as practicable, all loose bark and other conditions favorable for spinning up, and to provide instead bands of burlap or corrugated strawboard on the tree trunks for the worms to enter. If the scraping has been well done, large numbers of the larvæ may be trapped in these bands and destroyed. Catches of from 200 to 300 larvae per tree are not uncommon in heavily infested orchards.

To get the full benefit of the bands they must be placed in position in time to catch the early larvæ from the first brood as they seek spinning quarters. Every larva caught at this time is trebly important, since the death of one female moth of the first generation means an egg reduction of approximately 150 in the second generation and, of course, a much greater potential loss to the third.

If the bands are to prove of value rather than a detriment, they must be worked frequently. They afford ideal quarters for the larva and when they are not worked at least every 8 to 10 days during the season, they merely afford better and safer quarters for pupation, so that the infestation is increased rather than decreased.

Bands may be made of folded burlap or single-faced corrugated strawboard, and if untreated they should be at least 4 inches in width. Bolts of burlap may be cut in two lengthwise and each strip folded lengthwise to make three thicknesses and attached to the tree by hooking the ends over large finishing nails driven into the trunk. Such bands must not be chemically treated, however, since injury is likely to result where oil or chemicals are brought thus closely in contact with the tree for any considerable period.

Burlap bands, while offering somewhat more acceptable quarters than the corrugated paper, are considerably more expensive both to prepare and to run. As the expense involved in running every five to eight days during the growing season is considerable, there is a tendency to neglect it. For this reason it is recommended that untreated bands, either paper or burlap, be put on not earlier than the second week in August, and that they be used merely to concentrate the winter carry-over for convenient killing.

CHEMICALLY-TREATED BANDS

Corrugated-paper bands treated with chemicals to kill the larvæ may be applied safely early in the season, since they require no running to kill the trapped larvæ Such bands in the 3-inch width are effective apparently because the chemical closes the corrugations sufficiently to exclude the light. A mixture of 1 pound of alpha or

beta naphthol, usually the latter, and 1½ pints of red engine oil having a viscosity of about 300 seconds (Saybolt') is the material most commonly used in these bands. The action is rather slow, but apparently any larva that actually comes in contact with the material will die before transforming or emerging. In applying the bands care should be taken to chip off as little of the chemical coating as possible, and to see that they fit tight into all corrugations in the trunk.

While such bands can be made at home by following the instructions given by the United States Bureau of Entomology,[3] it is preferable to purchase bands made commercially, since the material is disagreeable to handle, the fumes affect the eyes and other mucous membranes, and the difference in cost is scarcely worth the trouble involved. The bands should always be handled with gloves, preferably leather, since the chemical may irritate the skin.

Experiments in southern Kansas have shown these bands to be somewhat less effective as catchers than the untreated burlap, but the low cost of placing them and their efficiency make them valuable aids in reducing the number of larvæ that successfully transform. Although little injury has been reported from the use of treated bands, it is advisable to remove them late in the fall and dispose of them by burning. Likewise precaution should be taken not to place the bands over the same area on the trunk in two successive years.

NATURAL ENEMIES OF THE CODLING MOTH

The codling moth has few insect enemies in southern Kansas. No parasites of larvae have ever been reported from this district and the common egg parasite, *Trichogramma minutum Ril.*, apparently gives little control even of the late broods. A few species of small beetles prey upon the cocooned larvae, especially where they occur in numbers. The total effect of these enemies, however, is very small. Fungous disease in occasional years causes fairly heavy loss where the larvae are in crowded quarters, but all these factors combined probably do not account for a total annual loss amounting to 10 per cent of the population.

Experience has shown, however, that while heavily infested trees may carry as many as from 300 to 500 larvae into the winter, in an average season it is doubtful if much over 5 per cent of these successfully pass the winter, and in unfavorable years possibly as low as only 1 or 2 per cent.

The reduction seems to be due to the severe weather, especially following rains, which causes freezing of the more exposed individuals, combined with the work of birds. The species of bird most commonly involved in southern Kansas seems to be the downy woodpecker, assisted by titmice, chickadees, and nuthatches, all of

3. Siegler, E. H., and Munger, F. Preparation and use of chemically treated corrugated bands as a supplemental control for the codling moth. Circ. E.-294, Bur. of Ent., U. S. Dept. of Agr. (7 mimeo. pages, 5 figures). April 1, 1932.

which industriously work over the trees during the entire winter. The more severe the weather the more closely do the birds work over the trees, especially if there is considerable snow, because under such conditions other sources of food are scarcer. Very mild winters, therefore, are likely to be followed by severe outbreaks.

RELATION OF ORCHARD CARE AND MANAGEMENT TO CONTROL

In areas of heavy infestation it behooves the orchardist to overlook no possible means of reducing the insect during the growing season or of reducing the carry-over from season to season.

CULTIVATION OF THE GROUND

Clean cultivation throughout the season is of some aid in control, as much of the dropped fruit from which the larvæ have not emerged is thereby better exposed to the action of the sun and many of such larvæ are killed by the high temperatures to which such fruit is subjected in contact with the earth.

The objection made to clean cultivation that it causes heat scald to the fruit, does not seem to have much evidence to support it locally, since the low-growing habit of the trees shades the main branches and most of the fruit from the effects of heat reflection except from the openings between rows. Some small losses of the fruit on branches sweeping the earth do occasionally occur.

PRUNING

Another aid in moth control is the proper pruning and heading of the trees. Experimental work has demonstrated conclusively that in large trees the control of worms is much poorer in the top sections than in the lower portions.

The heavy infestations found on brushy trees as compared with those on well-pruned open trees are also due to the inability to get good spray cover. Low heading and adequate pruning are thus shown to be great aids in controlling the codling moth during the growing season.

The number of trees per acre also markedly influences the degree of control possible. It is practically impossible to spray efficiently where the trees are so crowded as to prevent passage of the spray rig except in one direction, and so interlaced as to make it difficult to reach the two off sides of the tree from either the tower or the ground. The planting distance now most frequently used, 35 to 40 feet each way, is none too great for many varieties, such as York Imperial and Stayman Winesap, which grow to very large size in this district. Slightly decreasing the number of trees per acre in the case of the larger-growing varieties by increasing planting distance will pay in the end, since control of worms in the mature trees will be much better where it is possible to get at the whole tree with ease.

In southern Kansas the factor of good pruning and spacing is

frequently neglected. This results in orchards in which good control is difficult to attain, because of the impossibility of getting a uniform cover with spray material.

The tree should be pruned to a fairly open habit, leaving sufficient center to shade limbs and fruit and to give an adequate bearing area, but ruthlessly cutting out all brushiness and such limbs as, by their manner of growth, seriously interfere with entrance of spray into the interior. With varieties such as Grimes, this requires the exercise of considerable judgment to prevent undue loss of good-bearing wood in the interior of the tree. The main idea should be so to open the tree that the tower man can easily spray the interior opposite his stand. This can be accomplished often by keeping open small holes at intervals through the tree, or by pruning in such a way as to develop a layering system of branches, which do not interfere with spray by too erect growth. This latter system is especially easily applied to Winesaps and a few other varieties of similar growth habit.

Too much height in the tree must be avoided. The ideal system of pruning would permit the tower man to spray down upon the fruit. Since this ideal is impossible of attainment with most mature trees, the next best thing is to keep the tops as low as is consistent with good tree shape. Severe topping of tall-growing varieties and the development of a spreading type of growth so far as is consistent with reasonable strength of scaffold limbs for crop bearing ought to be encouraged. Since the choicest fruit in respect to size, color, and general quality is produced in the top, every effort should be made to prune the tree so that such fruit can be kept within the field of good spray cover.

PACKING-HOUSE SANITATION

The packing shed should be constructed tightly enough to prevent the exit of emerged moths in the spring. The shed should be darkened and a screened trap (fig. 6) constructed in the top for trapping moths upon emergence. These traps need no attention, since the moths beat themselves to death soon after entering them.

Lug boxes stored in sheds are a fruitful source of infestation for the ensuing season. If such boxes are left under open shelter through the winter, so piled as to permit sparrows and other birds to work through them, the population will be reduced very considerably. The boxes may be removed to closed sheds in the early spring in order to trap the remaining moths, if this is deemed desirable.

Fortunately the codling moth seems to be a relatively weak flier, and once it reaches apple trees it shows little tendency to go much farther. Even heavily infested sheds rarely affect the orchard for more than 4 to 6 rows from the nearest entry point, although the infestation on the trees in the first two or three rows may be so heavy as to cause practically total loss. Such rows should be most carefully sprayed and given one or two extra early-brood sprays to keep the infestation as low as possible.

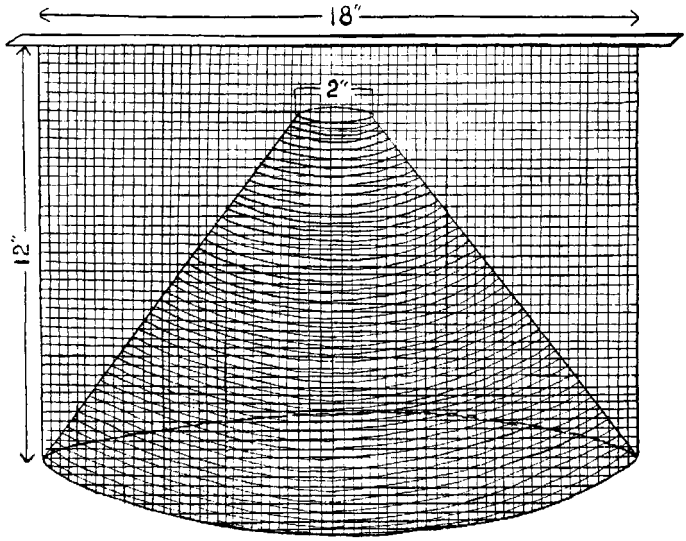


FIG. 6.—Plan of roof trap for adult codling moths, to be placed in roofs of packing sheds to take spring emergence.

ORCHARD INCOME AS AFFECTED BY SPRAYING PRACTICE

Inasmuch as the sole object in spraying is to obtain a larger quantity of commercially valuable fruit, certain practices that in themselves will control the codling moth effectively may be so expensive as to prevent the orchardist from realizing any profit on the fruit. This fact has been taken into consideration in making the recommendations for control that have been given herein.

Although the method of spraying here recommended costs more than the method usually followed, it is so effective in protecting the fruit that there is a distinct net gain. This is clearly brought out in a comparison between the method usually followed and the one here recommended as to spraying costs and income received. For the purposes of this comparison results were taken in 1929 from a block of trees sprayed under the commercial practice usual in the valley and from a similar block of trees in the experimental orchard of 20 acres handled by the field station. The trees counted in these two blocks were chosen early in the season because of similarity in variety and form as well as in crop set. From the average percentages of wormy and clean fruit from the trees of these two blocks, the percentages on 40-acre blocks of trees with an 80 per cent stand have been calculated, and used as a basis of comparison both of the costs or spray control and the income received from the fruit.

Spray costs based upon an average cost for chemicals and labor

taken over a period of six years are shown in Table II. The difference in labor cost between the usual and recommended methods is due to the fact that a somewhat better class of labor was employed by the field station to assure careful work. The item of dormant spray has been omitted, as well as other orchard expenses aside from actual spray costs. The income represents an average income for five years and was obtained by personal observation and questioning of orchardists in various parts of the valley. It is believed that these items represent a fair average estimate.

TABLE II.—COMPARISON OF THE COST OF SPRAYING BY THE USUAL METHOD AND BY THE RECOMMENDED METHOD.

ITEM OF COST.	Spraying by usual method.		Spraying by recommended method.	
	Requirement.	Cost.	Requirement.	Cost.
Lead arsenate	2,700 pounds	$324.00	8,500 pounds	$1,020.00
Copper sulfate	800 pounds	56.00	4,800 pounds	336.00
Slaked lime	1,600 pounds	16.00	9,600 pounds	96.00
Labor	3 men, 40 days at $75 per month	300.00	6 men, 60 days at $3 per day	1,080.00
Horse labor	40 days at $2	80.00	60 days at $4	240.00
Gas, oil, etc		15.00		40.00
Depreciation		150.00		300.00
Miscellaneous repairs, etc		25.00		50.00
Total cost		$966.00		$3,162.00
Average cost per tree		0.755		2.47

Difference in cost per tree, $1.715.

From the figures in Table II it may be seen that the expense by the recommended method is approximately three times that by the method now used in the valley, averaging $2.47 per tree against 75.5 cents for the usual method. This would be increased slightly if interest on invested capital were added, since by the recommended method two 200-gallon machines would be required in place of the one used under the usual method.

The income from the fruit, calculated in the same way for a 40-acre block, as obtained when the usual and the recommend spray methods are employed is shown in Table III. The orchard was estimated to carry an approximately 12,600-bushel potential crop set, a fair average from this acreage for mature trees. The fruit was graded on the basis of worm population only, grade-outs due to disease, small size, etc., being disregarded. Table III gives the fruit income in bushels according to three grades, and the probable money income from it. Harvesting and grading costs are not included.

TABLE III.—COMPARISON OF THE INCOME FROM FRUIT OBTAINED WHEN SPRAYING HAS BEEN DONE BY THE USUAL METHOD AND BY THE RECOMMENDED METHOD.

GRADE OF FRUIT.	Spraying by usual method.			Spraying by recommended method.		
	Total bushels.	Per cent of total.	Income.	Total bushels.	Per cent of total.	Income.
Clean	1,970	15.4	$1,576.00	10,230	80.0	$8,184.00
Stung only	3,180	24.8	2,226.00	1,410	11.0	987.00
Wormy	4,485	35.0	1,345.50	512	4.0	153.60
Drop before August 15	3,200	24.8	.....	640	5.0	.....
Total	12,835	100.0	.....	12,792	100.0	.....
Total income	.....	.....	$5,147 50	.....	.....	$9,324.60
Spray cost	.....	.....	966.00	.....	.....	3,162.00
Net above spray cost	.....	.....	$4,181.50	.....	.....	$6,162.60
Net per tree above spray cost	.....	.....	3.27	.....	.....	4.31

Difference in net income per tree, $1.54.

With fruit graded in this manner it is estimated, from six years' observation of prices, that the clean fruit will average approximately 80 cents a bushel orchard run in average years, the stung fruit approximately 70 cents a bushel, while the wormy and cider fruit combined will not average over 30 cents a bushel.

It will be noted that the drop before August 15 amounts in one case to 25 per cent of the set crop, and in the other to 5 per cent only. This fruit is of no value whatsoever, not being usable even for cider, and must be deducted from the money income in both cases. From these two comparisons it is found that although the spray costs by the recommended method are much higher than by the practices commonly used in this district, the recommended system will give a greater net profit.