The Connecticut
AGRICULTURAL
Experiment Station

Bulletin 313 March, 1930

# THE ORIENTAL PEACH MOTH IN CONNECTICUT

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## SUMMARY

1. *Damage from the Oriental peach moth* in Connecticut peach orchards annually amounts to more than $100,000.

2. *Its chief means of spread* lie in shipments of infested fruit; less important means in nursery stock movements and local flights of moths. Quinces and peaches are most seriously infested and few peach moth larvae have been found in other Connecticut fruits.

3. *The mature peach moth larva* is pink. Young ones are black-headed. Curculio larvae are curved and have yellow heads. Codling moth larvae and lesser apple worm larvae are more difficult to distinguish. (Page 407.)

4. *The peach moth's habits* are baffling and its defense almost perfect. Continuous generations in midsummer, the larval habit of digging in without eating materials placed on the surface and the ease with which peach trees are burned by insecticides, preclude use of extended spray schedules. (Page 409.)

5. *The life cycle* in peaches requires 32 days in midsummer and is divided among the various stages. Moths appear in early May and continue to emerge until mid-June. Three and sometimes a partial fourth generation of larvae occur, the first infesting twigs, the second twigs and fruit, and the third fruit.

6. *Field experiments* with bait pans, lime, and talc have given little or no control of the larvae in fruit. (Page 428.) Nicotine sulfate and white oil emulsions have afforded more control, but not enough to warrant recommending them. (Page 428.) The cost of the last two is also prohibitive. Cultivation seemed to give good results when it was first used at Wallingford, but it was not effective at Southington. (Page 435.) Paradichlorobenzene, heretofore recommended for wintering peach moth larvae, is usually applied before the majority spin. (Page 435.)

7. *A number of laboratory* control experiments have been conducted. (Page 413.)

8. *Attempts at colonization of the parasites Trichogramma minuta* and *Macrocentrus ancylivora* were made in 1929. (Pages 440 and 443.)

9. *At the request of orchard owners* artificial propagation of parasites has been started, using funds contributed in part by the growers themselves.

## CONTENTS

# THE ORIENTAL PEACH MOTH IN CONNECTICUT

Philip Garman

The Oriental peach moth[1] is probably the worst enemy with which peach growers in Connecticut have to deal today. Because of the great difficulty of controlling it by any known sprays or other practices, it has attracted more and more attention on the part of growers, while the monetary loss has continued to mount into thousands of dollars annually. The insect was found in Connecticut about 1917, but it was not until 1924 that growers felt commercial damage. Between 1924 and 1929 it gained in destructiveness, infesting more and more orchards, in many of which it has been difficult to obtain sound fruit.

Considering the insect to have been in Connecticut since 1917 and our present infestation to be now at its height, it will be seen to have required 10 to 12 years to reach destructive numbers. Reports from available sources during 1925-1929 showed distinct advances in Connecticut on the part of the peach moth, although it was slow in establishing itself in many orchards and in a few seemed to decrease. Figures 26 to 28.

Much of the information contained herein has already been published, but the demand for literature about the insect has increased so much that it seems desirable to assemble it in one publication.

## HISTORY IN THE UNITED STATES

Briefly, the history of the peach moth in the United States is as follows: The United States Department of Agriculture discovered it about 1916 near Washington, where it became destructive in the years 1917 to 1919. From this point it has seemed to spread almost in the form of a circle increasing in diameter from year to year, until at present practically all peach-growing states east of the Mississippi and portions of Canada are infested. The damage probably runs into millions of dollars every year.

### Origin

The true origin of the peach moth is probably not known. It came to this country from Japan in flowering cherries, but Japanese authorities maintain that it was not there before 1899. It is

[1] *Grapholitha* (*Laspeyresia*) *molesta* (Busck); *Cydia molesta* (Busck) in British literature; order Lepidoptera, family Tortricidæ. Known also as the Oriental fruit moth, Oriental peach worm and Oriental fruit worm; in Japan as the smaller pear borer. It has been called the peach tip moth in Australia.

present now in Australia, Japan, China (Manchuria), Korea, Italy, France, Canada, United States, and probably in other countries. It has been reported as doing considerable damage in most of the regions where it is found, but appears to be less important in Australia and Italy than in others.

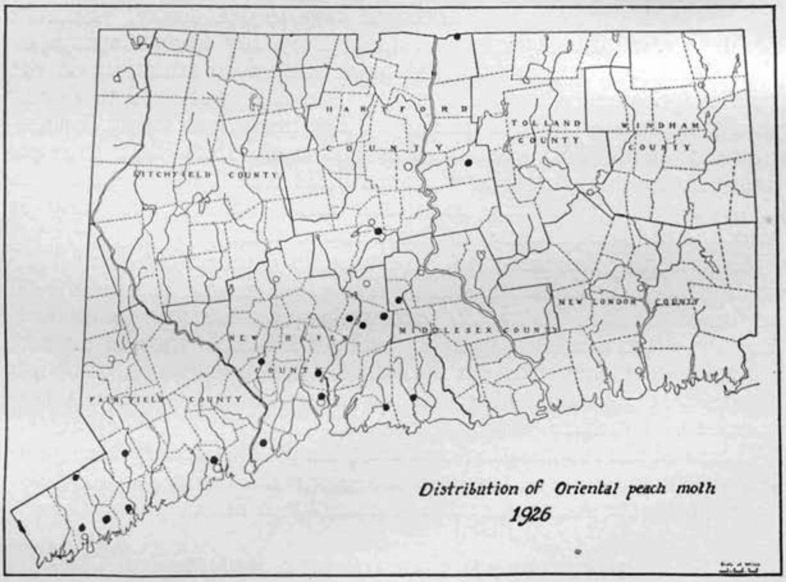


FIGURE 26. Map of Connecticut showing recorded distribution of the Oriental peach moth in 1926.

## Methods of Spread

The Oriental peach moth flies readily in the adult stage and can therefore travel from orchard to orchard in any given locality. It is known to infest nursery stock and some are doubtless carried on young trees, since the over-wintering cocoons on the trunks or branches are very difficult to detect. The most important means of spread, however, lie in the shipment of wormy fruit, which sometimes comes into Connecticut in considerable quantities, and in the local distribution of fruit from town to town or district to district, which results in a steady increase of the general infestation. Containers of various kinds, such as barrels, peach baskets or bushels, in which fruit has been stored and in which the larvae frequently spin for hibernation are also important sources of danger and spread.

## Injury

The amount of injury in different orchards varies considerably. As a rule, in orchards carrying 10 per cent or less of wormy fruit, the damage is not noticed, but when it averages much higher, it causes trouble in sorting, increase in brown rot and reduced sale value. Such fruit requires careful sorting because of the disagreeable gummy appearance, while much that remains, even after the greatest care has been taken, may contain larvae which have entered without leaving a trace. If there is much worminess

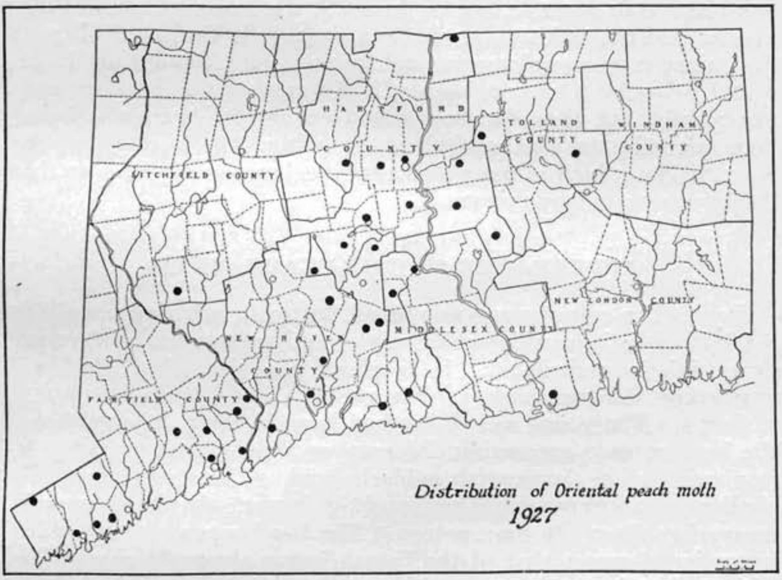


FIGURE 27. Map of Connecticut showing recorded distribution of the Oriental peach moth in 1927.

invisible from the outside, the peach finds its way into the hands of the consumer, sometimes with undesirable results. Dropped fruits resulting from an infestation are shown on Plate XI, b.

We have seen orchards in the central part of the State carry 50 to 100 per cent of infested fruit, and in some instances, the fruit may contain more than a single larva per peach. In quinces, the infestation is often more severe than in peaches, so that where the quinces are heavily infested, each fruit may contain several larvae. We have counted as many as five larvae in a single quince and under some conditions even more than this may be found. The damage to apple and pear fruits has been slight so far in Connecticut. Reports of injury to apples amounting to 50 per cent of the crop is reported from states to the south, but no cases of this sort have come to our attention. Most injury reported as peach moth injury, thus far investigated, has proved to be codling moth or lesser apple worm and not the Oriental peach moth.

The peach moth infests occasionally other fruits, such as cherry, Japanese quince, apricots and nectarines, but it has not yet been seen to do extensive damage to these plants in Connecticut. Pears are said to be heavily infested in Japan.

The amount of damage to peaches was estimated by Mr. Harold M. Rogers, president of the Connecticut Pomological Society, to be $150,000 or more in 1928. In 1929, the loss was considerably greater and the estimates probably averaged $200,000. This year the quince crop was almost a total failure, and although not large, would raise the total considerably. Figures of this sort are estimates only, but they do show that tremendous damage is being done annually to the peach business within the borders of the State, a loss which is most discouraging because of the fact that the injury cannot be prevented.

## APPEARANCE OF THE PEACH MOTH

*Egg.* The egg appears as a small flat scale adhering closely to the leaf or fruit, usually white, often semi-transparent, and sometimes faintly reticulated. It is about the size of a pin-head, measuring .5-.7 mm. across. Plate VIa, c.

*Larva.* The young newly-hatched larva is about 1.4 mm. long, the head capsule measuring .22 mm. or about .1 of an inch. It is a small white larva with a black head. The second instar is similar in appearance, being slightly larger, the head capsule measuring about .36 mm. across. The head capsule of the third instar is .64 mm.; that of the fourth instar about .81 mm. The fifth or last instar measures 12 mm. or about .5 inch in length, while the head capsule measures on an average 1.0 mm. In this instar, the head turns brownish in color, and the body becomes pinkish. The over-wintering larva tends to become shorter and thicker than mature summer larvae. Plate V, a; VII, b.

*Pupa.* The pupa is brownish in color, turning nearly black just before the adult emerges. It is 6-7 mm. in length.

*Moth.* The adults (Plate VI, a, b) are small grayish-brown moths, with wings silvery on the under surface and figured with light wavy lines above. They are inconspicuous when the wings are folded. The male and female are similar, but the male abdomen is more slender than the female's. The appendages of the two sexes are shown in Figure 32, A and B; wing spread 12.5 mm. (.5 inch); body length 4-5 mm. (about .2 inch). Wing venation of the female is shown in Figure 31.

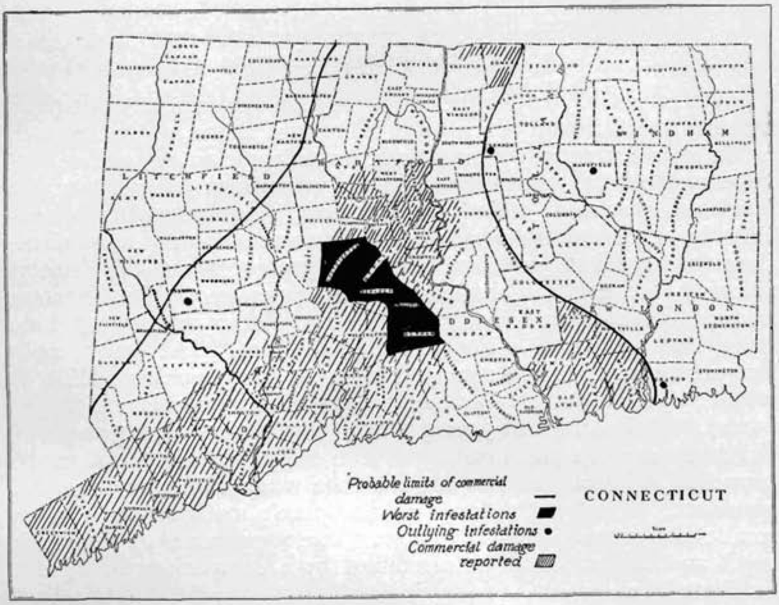


FIGURE 28. Map of Connecticut showing distribution of the Oriental peach moth in 1928. In 1929 the black area spread over Hartford County and northeast to and beyond the line of commercial damage in 1928.

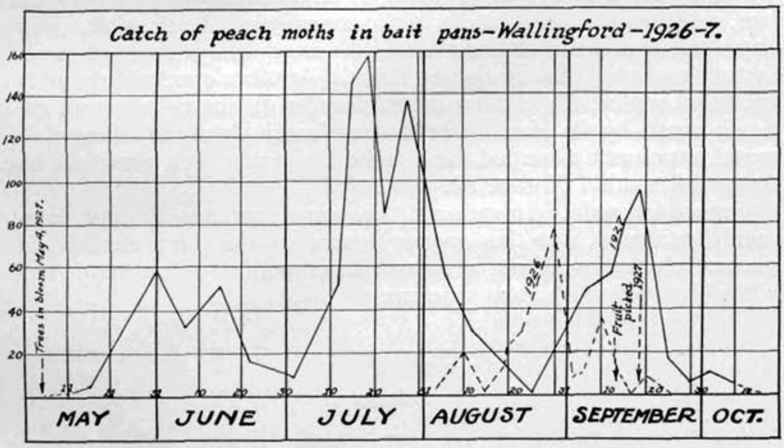


FIGURE 29. Periods of adult Oriental peach moth activity in 1926 and 1927. This shows the relative abundance at different periods during the summer, in an Elberta orchard. It also shows that the peak of the third generation varies from year to year in the same orchard.

## Differences between the Peach Moth Larvae and Other Similar Larvae

*Plum curculio.* It becomes important on occasion to distinguish between the Oriental peach moth larva and larvae of insects such as the plum curculio, codling moth, lesser apple worm, quince curculio and others. In peaches certain conditions tell whether the peach moth or some other pest is present. For example, the curculio larva, one of the most commonly encountered, is most abundant in June and July and is rarely present when the fruit is ripening—at least in Connecticut. The peach moth, furthermore, becomes pinkish when full grown; the curculio larva never does, being more often a white or yellowish tint. The peach moth frequently makes more of a gummy mess at the surface, filling it with excrement, except for the late entries where no trace can be found. If the twigs of young peach trees or new rank growth of old trees are examined, many of the twigs will be found to be tunnelled, whereas, this is not the case when curculios alone are abundant. Finally, the head of the peach moth is black when small; the curculio head is yellow. The appearance of the peach moth and curculio may be visualized by a comparison of figures on Plate V, a.

*Apple worms.* There is greater difficulty distinguishing the Oriental peach moth larva from that of the lesser apple worm, especially in the younger stages, since both have nearly the same microscopical characters and general appearance. When older, the larva of the lesser apple worm takes on a decided orange hue, whereas the peach moth larva remains a delicate pink. For those not specialists in the group, this is probably the most satisfactory means of distinguishing them. Another species commonly found in apples, the codling moth, may be distinguished from the peach moth by its size. The codling moth is usually larger, is more prominently spotted, and lacks the anal comb possessed by the peach moth. Figure 30.

*Quince curculio.* In quinces, the quince curculio is most commonly confused, but this species resembles the plum curculio in general characters, being a curved larva with a yellow head, and whitish or yellowish in appearance.

## HABITS

### Adult

Adults emerge during the day, usually resting awhile before becoming active. They fly most actively towards sundown, but have also been observed (25) in the middle of the day. Eggs are laid for an hour or two before and after sundown and some in early morning. Mating takes place usually within two days after emergence from the cocoon and egg laying commences shortly afterwards. The moth requires some water and food (sugars) since it is attracted to fermenting baits and seeks such food in cages. In general, the flight is very irregular, most of the moths apparently remaining near the tops of the trees when in flight,

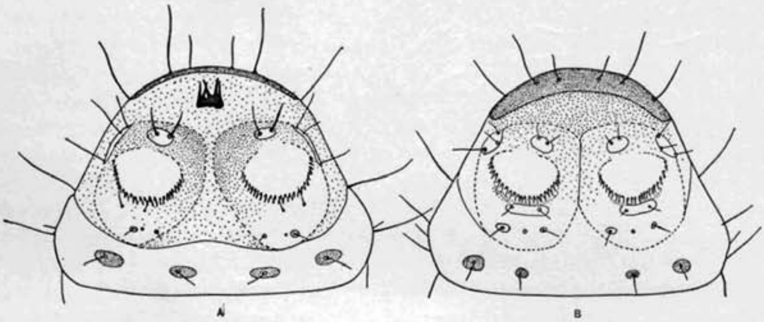


FIGURE 30. Anal segments of larva of (A) Oriental peach moth and (B) the codling moth, showing difference in structure.

and progressively fewer being found on approaching the ground. As already mentioned, they are attracted to baits and to some

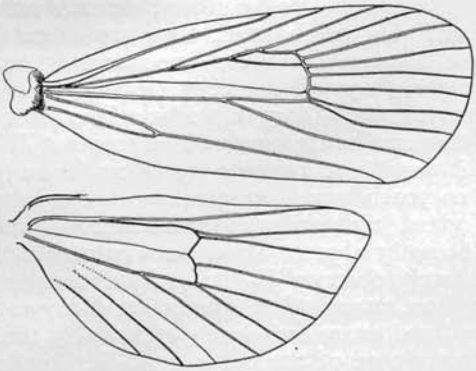

FIGURE 31. Wings of the Oriental peach moth with scales removed, showing veins.

extent to lights. Peterson has shown that ultraviolet rays are most effective (46).

In captivity, warmth and humidity are required before many eggs are deposited and crowded conditions are conducive to high egg yields. Moths lay best, in our experience, when kept in a warm tent with added heat about sundown, particularly if the weather is cool. If not cool, no additional heat is necessary. If very hot, 90-100°, the moths suffer and many die without laying. Humidity above the average is desirable. A cage used for confining the moths is shown on Plate XI, a.

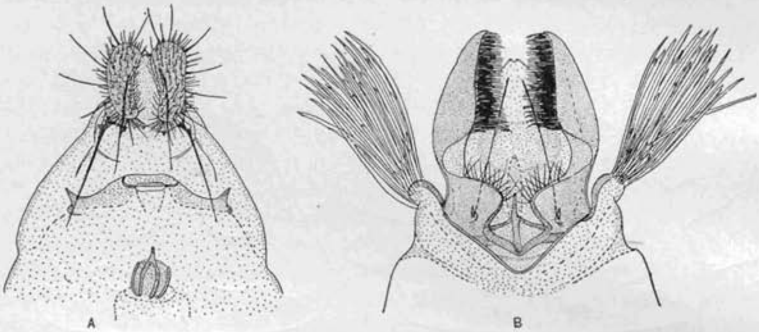


FIGURE 32. Tip of the abdomen of (A) the female and (B) the male peach moths, showing details of structure.

Eggs are laid on peach leaves usually on the under side, sometimes on the upper side and on the stems, but never on the fruit itself. On quinces, they may be deposited on upper or under surfaces of the leaves, on the sepals of the fruit, or on the fruit itself. The eggs are said to be placed directly on the fruit of pears, in Japan. On peach trees, they are often deposited on leaves at some distance from the fruit or twig that the larva infests. In cages, they will lay eggs on almost any material of the desired smoothness. Many eggs have been obtained on wax paper when the moths are confined in cages (71), a scheme which makes it possible to rear the insect continuously during the winter when no peach leaves are available for oviposition. They will lay on glass, tin, or even smooth wood surfaces when compelled to do so by absence of surfaces natural to them.

Moths are rarely observed in the orchard except towards sundown. Even then, many other species are likely to be confused unless captured and examined closely. Probably the best way to determine the presence of the peach moth lies in the use of bait pans, which are discussed on page 428. The moths are easily recognized in such pans, especially during midsummer, when many may be seen floating on the surface of the bait.

## Larva

On hatching, the minute larva slips out from the side of the egg, and being very active, soon finds a suitable twig or fruit where it starts immediately to work. It usually enters peach twigs near, but a little below, the actively growing tip sometimes through the base of the leaf. Plate I, a, b, shows typical twig injury. Peaches are entered near the stem, or through the stem itself (Plate II, a), leaving little or no trace at the point of entry. Sometimes the fruit is entered through the side, especially if two fruits or a fruit and a leaf are in contact. Plate II, b; III, a. Quinces are usually entered through the calyx end, though occasionally at other points. Plate IV. It is well known that the larva, on burrowing into the fruit or twig, throws aside the first mouthfuls until well below the surface. This is also true of the larvae that transfer from twig to twig when partly grown, or from twig to fruit. The habit makes the insect very difficult to kill because of the fact that whatever poisons may be present on the outside of the fruit or twig are automatically discarded.

In peach twigs, the larva continues to feed on the central core until mature, unless forced out by an accumulation of gum, when it seeks another twig or fruit to continue its development. Two to three twigs may be tunnelled by a single larva.

In peaches the larva, for the most part, continues to eat next to the pit (Plate III, b), excavating a hole of considerable size and filling it with excrement. When fully grown, it bores through the side of the fruit and seeks quarters for cocooning. Only one fruit is usually infested by a larva.

The behavior in quinces is essentially the same as for peaches, except that the larva seems to wander about more in the flesh, making tortuous tunnels throughout.

In apples, the tunnels are similar to those in quinces. They differ from the usual work of the codling moth, which burrows directly to the core if it enters through the calyx or if through the side, after making a shallow mine under the skin. Young larvae have great difficulty entering through the skin of the apple, which probably accounts for their present scarcity in this fruit in Connecticut. They are, however, reared very easily in this fruit when points of entrance are provided and either ripe or green apples may be used.

## Cocoon and Pupa

After leaving the fruit the larvae spin or crawl down seeking quarters to transform either on the ground or on the trunk of the tree. A small percentage spins on the branches of the tree itself. They will seek hollow stems and will spin on the soil itself, boards, or even dried peach mummies lying on the ground. On the trunk, they most frequently crawl under a flap of bark, sometimes abandoning a cocoon after construction, evidently because of an unsuitable location. The cocoon itself is constructed of fine silk, and is covered with bits of bark or other material taken from the material on which the cocoon is constructed. If the soil is well cultivated at the time of spinning, many are naturally forced to the trunk and spin within a few feet of the ground. During the winter, a majority of the larvae on the trunks will be found on the north side, but there are many that also spin in other locations. The general tendency, however, seems to be to spin away from the sun.

The cause of hibernation may naturally be attributed to cold, either its effect upon eggs, larvae or adults. However, in 1929 there was considerable hibernation (34 per cent) of larvae obtained frôm eggs placed July 19 immediately after oviposition in an incubator kept constantly at 70° F. From this, it would seem that whatever conditions affected hibernation were *present when the eggs were laid,* and they may be enzymatic in nature as suggested by Shelford,[1] rather than due to effects of temperature.

## SEASONAL LIFE HISTORY

Moths emerge from hibernation in Connecticut during the middle or fore part of May and continue to emerge for probably a month under normal conditions. There is a considerable difference in the time of emergence, depending on the location of the cocoon, that is, whether protected from the sun or not. Under normal conditions shade is provided by the foliage shortly after warm weather begins, so that delayed emergence takes place. Bait pan records indicate that moths are most abundant about the first of June, and this corresponds in general with our insectary records. When placed in warm tents such as were provided in 1929, or exposed to direct sunlight, appearance of the moths is much earlier, but in Connecticut we have seen no evidence of advance emergence in the field. In packing houses or cold storage plants, however, emergence is much later and where these are near bearing orchards it will doubtless effect the sequence of the broods appearing in the orchards nearby.

The various flight periods of the adult are essentially as shown in Figure 29, but it has been observed in two years in two different orchards that the greatest number of moths were caught in bait pans during the middle of July or at the height of the second brood. In 1929 the number exceeded 1,000 a week in 20 bait pans during this period, whereas it dropped considerably below that figure in both June and August. In 1926, however, there were more moths caught in June than in July or August, although during that year all three broods were about equal. The reason for these conditions can only be surmised but may be connected in some way with the hibernation of certain individuals or in parasitic action.

[1] Laboratory and Field Ecology, 169. 1929.

The eggs of the first brood are laid beginning in May and continuing until the latter part of June and those of the second and third generations from July to late September.

Larvae are found in the fruit or twigs following the course of egg-laying activity, as shown in Figure 33. Larvae of the second generation may enter peaches in small numbers, but the number

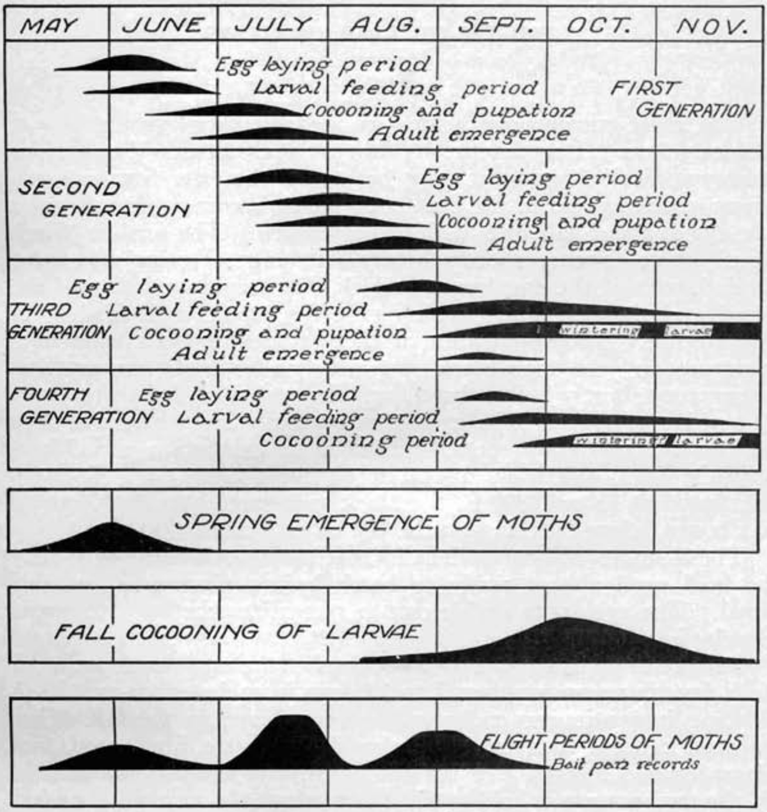


FIGURE 33. Life history chart of the Oriental peach moth.

increases rapidly with the appearance of the third brood and the ripening of the fruit. Hibernation tendencies begin to be apparent shortly after the first of August.

Emergence from fruit takes place during August, September and October and may continue until December. In 1928 the majority of larvae left the quinces and peaches in October and some the first part of November, while few or none emerged from the fruit after this date. In 1929 the emergence from fruit was apparently much earlier and although it again continued during October, it probably reached its peak in September of this year. The year 1928 was a wet one; 1929 very dry.

Spinning takes place, of course, shortly after leaving the fruit.

Spring pupation of the larvae began in 1929 in the first week in April and continued until June, approximately half being transformed by the first week in April.

## LENGTH OF LIFE PERIODS

### Egg

The most conspicuous stages of the egg development appear several days after laying. Without considering the various embryological changes, it may be stated that the first external signs of life appear in the eye spots, which become apparent when the egg is about half or two-thirds developed. The final or "black spot" stage appears shortly before hatching. During the latter period, part of the egg becomes dark, due to pigmentation of the head and thoracic shield which give the whole a decided black appearance. The appearance of these stages depends upon temperature and the true black spot may under high temperatures occur very shortly before hatching. In cool periods it often lasts for a day or more. The eye spots normally appear several days before the egg "black-spots." Thus in an incubation period lasting six days, eye spots appeared on the fourth day. In eggs incubated at 75 and 80° F. the black spot stage appeared four to six hours before hatching on the last day of incubation.

These stages are convenient in insectary work since eggs may be held until almost ready to hatch before placing on suitable food. The eye spots enable one to recognize whether the egg is developing normally.

Peterson and Haeussler (45) state that the egg develops in 3.5 to 6 days in warm weather, 7 to 14 days in cool periods and 20 to 43 days in continuous cool weather experienced in the fall. Our records indicate an average of nine days for the first brood, five days for the second, five for the third, and 7.6 for the fourth. If the temperature is held to 60° F. or below, the incubation period increases accordingly and it is very likely that eggs laid in September would in all probability remain two weeks or more before hatching and the larval development would likewise be slow afterwards. Our experience indicates that eggs will hatch in 3.5 to 4 days at 90° F., but require 12 to 15 days when the thermometer remains at about 60.°

### Larva

The length of the larval feeding period averaged in 1925-26 15.6 days for the first brood, 12.8 days for the second and 18.1 days for the third. Quality of the food makes considerable difference in the length of the stage, it being noted that a single instar reared on some of the prepared foods experimented with, required as much time as the entire larval period on normal foods. We know also that larvae fed on apples require a longer period to mature than those fed on peaches. The life cycle in quinces has, however, not been studied carefully.

### Cocoon and Pupa

The time spent in constructing the cocoon varies from two to four days in midsummer. For the first and second broods this is approximately two days. For generations that hibernate, this is, of course, much longer. The pupal period averaged about 11 days for the first, second and third generations in 1925 and 1926. The period in spring, however, is somewhat longer.

### Adult Moth

The female begins to lay eggs two to four days after emergence. Mating usually takes place within two days after emergence. There is then a period of about a week[1] when the eggs are deposited, and the adult may continue to live as much as a week longer. In field cages (Plate X, a) they have been observed to live for two to three weeks, while in smaller cages they rarely live more than 10 days. The maximum egg deposition occurs on the third and fourth days after emergence in midsummer.

## LABORATORY EXPERIMENTS

### Control of the Eggs

During 1928, preliminary tests were carried out with white oil emulsions containing various impregnating materials. These tests showed a high mortality for eggs sprayed with white oil plus pyrethrum soap, indicating at least 15 per cent better kill for such a combination than was formerly obtained with nicotine sulfate and soap as reported by Stearns (61). The work was continued in 1929 and the results are shown in Tables 2 to 11. The figures indicate that some of the commercial white oils on the market give a very good kill without additions, but that in general they average slightly higher when combined with the materials mentioned. It will be noted that these tests were made from June to August during the usual spray range for Elberta peaches and include eggs of many stages of development. In all about 7,000 eggs were used together with a total of more than 400 for 1928. No checks are shown in the tables, although some were used with

[1] Longer under some conditions.

TABLE 1. LIFE HISTORY DATA ON THE ORIENTAL PEACH MOTH, 1925-1926

Incubation of the Egg—Days

| Date | First Brood | | | Second Brood | | | Third Brood | | | Fourth Brood | | | Total observations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. observed | Average | Range | No. observed | Average | Range | No. observed | Average | Range | No. observed | Average | Range | |
| 1925 ............ | 276 | 9.0 | 3–13 | 155 | 4.8 | 4–6 | 39 | 4.9 | 4–6 | 34 | 7.6 | 6–11 | |
| 1926 ............ | 268 | 9.3 | 6–16 | 125 | 4.9 | 2–6 | 142 | 5.3 | 3–7 | | | | |
| Aver. for 1925-6.. | 544 | 9.1 | 3–16 | 280 | 4.8 | 2–6 | 181 | 5.1 | 3–7 | 34 | 7.6 | 6–11 | 839 |

Larval Feeding Period—Days

| Date | First Brood | | | Second Brood | | | Third Brood | | | Total observations |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. observed | Average | Range | No. observed | Average | Range | No. observed | Average | Range | |
| 1925 ............ | 26 | 15.4 | 13–20 | 42 | 13.2 | 10–17 | 16 | 16.5 | 12–28 | |
| 1926 ............ | 63 | 15.8 | 12–27 | 64 | 12.4 | 10–21 | 92 | 19.8 | 14–34 | |
| Aver. for 1925-6.. | 89 | 15.6 | 12–27 | 106 | 12.8 | 10–21 | 108 | 18.1 | 12–34 | 403 |

Cocooning and Pupal Period—Days

| Date | First Brood | | | Second Brood | | | Third Brood | | | Total observations |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. observed | Average | Range | No. observed | Average | Range | No. observed[1] | Average | Range | |
| 1925 ............ | 17 | 13.4 | 9–17 | 36 | 13.3 | 9–16 | 11 | 13.2 | 12–16 | |
| 1926 ............ | 78 | 12.8 | 8–15 | 72 | 12.5 | 8–18 | | | | |
| Aver. for 1925-6.. | 95 | 13.1 | | 108 | 12.9 | 8–18 | 11 | 13.2 | 12–16 | |
| Egg to Adult.... | Sum | 37.8 | 23–60 | | 30.5 | 20–45 | 11 | 36.4 | | 214 |

Total Period[2]—Egg to Adult—Days

| Date | First Brood | | | Second Brood | | | Third Brood | | | Total observations |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. observed | Average | Range | No. observed | Average | Range | No. observed | Average | Range | |
| 1925 ............ | 30 | 35.2 | 29–43 | 66 | 32.4 | 29–38 | 22 | 281.7 | 271–294 | |
| 1926 ............ | 102 | 39.0 | 31–49 | 80 | 30.3 | 26–37 | 56 | 286.8 | 259–318 | |
| Aver. .......... | 132 | 37.1 | 29–49 | 146 | 31.3 | 26–38 | 78 | 284.2 | 259–318 | 356 |

[1] Only those emerging before winter are recorded.
[2] Records of continuous periods from egg to adult.

each test, because at no time did more than 10 per cent fail to hatch. The average mortality of all checks was five per cent. It should also be remarked that very favorable results were obtained with one per cent oils containing about 20 per cent of steam distilled pine oil (straw color); in fact, a higher kill was obtained with this than with any other combination. Oleoresin capsicum-soap emulsions also seemed to have some killing power, as shown in Table 10. Judging from the amount of control secured with white oil emulsions, these materials should show some control in the field and this has been substantiated in part by our 1929 results. The degree of control, however, in these tests has not been any better than was previously obtained with nicotine preparations, but owing to differences in methods of applications and time of applications ought not, perhaps, to be compared.

The laboratory tests described were conducted in an outdoor insectary with eggs produced under artificial conditions. All tests were handled the same way, the sprays being applied with a small atomizer. The same nozzle was used each time and the peach leaves containing the eggs were pinned to a rack in the open insectary that had good ventilation, but was protected from sunlight.

TABLE 2. EXPERIMENTS WITH SPRAYS TO KILL THE EGGS OF THE ORIENTAL PEACH MOTH IN 1929

Lubricating Oils

| Exp. No. | Materials | Eggs laid | Treated | Examined | No. dead | Hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 38 | W. O. E.,[1] light 6 gm. Water to 600 cc. .... | June 17 | June 19 | June 24 | 73 | 9 | 89 |
| 24 | W. O. E., 6 gm. | | | | | | |
| 24 | Water to 600 cc. .... | May 30 | June 3 | June 10 | 108 | 6 | 94 |
| 11 | W. O. E., light 4 gm. Water to 600 cc. .... | May 27 | May 29 | June 3 | 15 | 3 | 83 |
| 35 | W. O. E., light 3 gm. Water to 600 cc. .... | June 11 | June 12 | June 18 | 47 | 26 | 64 |
| 30 | White Oil A, 6 gm. Soap 2 gm., Water to 600 cc. ............ | June 8, 9 | June 11 | June 18 | 71 | 7 | 91 |
| 44 | W. O. E., light 6 gm. Water to 600 cc. .... | July 12–14 | July 16 | July 22 | 171 | 54 | 76 |
| 48 | W. O. E., light 6 gm. Water to 600 cc. .... | July 13 | July 17 | July 22 | 88 | 23 | 79 |
| 49 | W. O. E., Conc. 6 gm. Water to 600 cc. .... | July 13 | July 17 | July 22 | 149 | 8 | 94 |
| 53 | W. O. E., Conc. 6 gm. Water to 600 cc. .... | July 24 | B. Spot | July 30 | 100 | 18 | 84 |
| 54 | W. O. E., light 12 gm. Water to 600 cc. .... | July 24 | B. Spot | July 30 | 90 | 5 | 94 |
| 56 | W. O. E., Conc. 6 gm. | July 23 | July 24 | July 30 | 67 | 15 | 81 |
| | W. O. E., Conc. 6 gm. | B. Spots | Aug. 27 | Aug. 29 | 35 | 12 | 74 |
| | W. O. E., Conc. 6 gm. | Aug. 22 | Aug. 24 | Aug. 29 | 77 | 13 | 85 |

[1] W. O. E.—A commercial white oil emulsion; light—viscosity of oil 50 sec.; concentrate, 108 sec. White oil A—a white lubricating oil of 90 sec. viscosity with 96 per cent. unsulfonatable.

TABLE 3. Lubricating Oils, Laboratory Made Emulsions

| Exp. No. | Material | Total oil content | Date eggs laid | Treated | Eggs examined | No. dead | No. hatched | Per cent dead |
|---|---|---|---|---|---|---|---|---|
| 131 | 20% pine oil, 80% white oil A Mineral oil soap | .5% | May 24–25 | May 28 | June 4 | 30 | 4 | 88 |
| 135 | Same | .5% | May 28–29 | May 31 | June 4 | 158 | 21 | 88 |
| 138 | 20% pine oil, 80% white oil A Milk | .5% | May 31 | June 4 | June 11 | 38 | 4 | 90 |
| 161 | 20% water white pine oil, 80% white oil A Milk | .5% | June 19 | June 20 | June 25 | 63 | 8 | 88 |
| 163 | Same | .5% | June 22 | June 25 | June 29 | 57 | 0 | 100 |
| 179 | Same | .5% | July 9 | July 10 | July 15 | 27 | 0 | 100 |
| 194 | Same | .5% | July 16 | July 17 | July 24 | 96 | 17 | 85 |
| 202 | Same | .5% | July 20 | July 22 | July 27 | 184 | 35 | 84 |
| 225 | Same | .5% | July 25 | July 27 | July 31 | 74 | 18 | 80 |
| 189 | Same | 1.0% | July 12–14 | July 16 | July 22 | 76 | 3 | 96 |
| | **Pure Oils** | | | | | | | |
| 150 | Pine oil-milk | 1.0% | June 8–9 | June 11 | June 17 | 68 | 27 | 71 |
| 151 | Water white kerosene-milk | 1.0% | June 10 | June 11 | June 17 | 68 | 11 | 86 |
| 146 | Oil A-milk | 1.0% | June 5 | June 7 | June 13 | 92 | 3 | 96 |
| 166 | Same | 1.0% | June 22 | June 25 | June 29 | 46 | 20 | 69 |
| 191 | Same | 1.0% | July 13–14 | July 17 | July 22 | 92 | 6 | 94 |
| 198 | Same | 1.0% | July 16 | July 19 | July 24 | 82 | 8 | 91 |
| 211 | Same | 1.0% | July 24 | July 25 | July 30 | 59 | 20 | 74 |
| 241 | Oil A-milk | 1.0% | July 31 | Aug. 2 | Aug. 7 | 155 | 0 | 100 |
| 264 | Oil B-milk | 1.0% | Aug. 19 | Aug. 20 | Aug. 26 | 90 | 4 | 95 |
| 279 | Same | 1.0% | Aug. 23 | Aug. 26 | Aug. 30 | 175 | 9 | 95 |
| 153 | Oil B-milk | 1.0% | June 12 | June 13 | June 18 | 91 | 3 | 96 |
| 167 | Same | 1.0% | June 22 | June 25 | June 29 | 45 | 7 | 86 |
| 192 | Same | 1.0% | July 13–14 | July 17 | July 22 | 120 | 0 | 100 |

TABLE 3. Lubricating Oils, Laboratory Made Emulsions (Continued)

| Exp. No. | Material | Total oil content | Date eggs laid | Treated | Eggs examined | No. dead | No. hatched | Per cent dead |
|---|---|---|---|---|---|---|---|---|
| 199 | Same | 1.0% | July 16 | July 19 | July 24 | 76 | 19 | 80 |
| 210 | Same | 1.0% | July 24 | July 25 | July 30 | 85 | 13 | 86 |
| 242 | Same | 1.0% | July 31 | Aug. 2 | Aug. 7 | 252 | 3 | 98 |
| 265 | Same | 1.0% | Aug. 19 | Aug. 20 | Aug. 26 | 87 | 5 | 94 |
| 209 | 56-oil-milk | 1.0% | July 24 | July 25 | July 30 | 68 | 22 | 75 |
| 240 | Same | 1.0% | July 31 | Aug. 2 | Aug. 7 | 125 | 7 | 94 |
| 262 | Same | 1.0% | Aug. 19 | Aug. 20 | Aug. 26 | 103 | 1 | 99 |
| 280 | Same | 1.0% | Aug. 23 | Aug. 26 | Aug. 30 | 101 | 4 | 96 |
| 291 | Same | 1.0% | Aug. 28 | Aug. 30 | Sept. 9 | 216 | 16 | 93 |

Notes

| Oils used | Per cent unsulfonatable | Viscosity Saybolt |
|---|---|---|
| 56 oil | 97 | 58 |
| White oil A | 96 | 90 |
| White oil B | 98 | 160 |

Pine oils in Nos. 131, 135, 138 and 150 straw-colored; in all others, water white.

TABLE 4. EXPERIMENTS WITH SPRAYS TO KILL THE EGGS OF THE ORIENTAL PEACH MOTH, 1929

Lubricating Oils with Additional Contact Insecticides

1. Pyrethrum products

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed | Notes |
|---|---|---|---|---|---|---|---|---|
| 1 | W. O. E.,[1] 1.6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | May 23 | May 24 | May 29 | 24 | 3 | 89 | |
| 16 | Same as 1 ......... | May 28 | May 30 | June 10 | 85 | 13 | 86 | |
| 50 | W. O. E., conc. 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | July 13 | July 17 | July 22 | 93 | 4 | 96 | Actual kill, including dead larvae, 98% |
| 51 | W. O. E., light 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | July 13 | July 17 | July 22 | 109 | 9 | 92 | |
| 52 | W. O. E., conc., 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | B. spot | July 24 | July 30 | 187 | 11 | 94 | |
| 55 | W. O. E., conc., 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | July 23 | July 24 | July 30 | 152 | 10 | 94 | |
| | W. O. E., conc., 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | Black spots | Aug. 27 | Aug. 29 | 61 | 9 | 87 | |
| | W. O. E., conc., 6 gm., Pyrethrum soap, 1 gm., Water to 600 cc. .... | Aug. 22 | Aug. 24 | Aug. 29 | 103 | 12 | 89 | 2 dead on leaves after hatching. Actual kill 90% |

[1] White oil emulsions.

TABLE 5. Lubricating Oils with Additional Contact Insecticides

2. Derris and similar materials

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 34 | W. O. E.,[1] 1.3 gm., Derris preparation, 1 gm., Water to 600 cc. .................... | June 11 | June 11 | June 18 | 27 | 18 | 60 |
| 18 | W. O. E., 1.6 gm., Derris preparation, 1 gm., Water to 600 cc. .................... | May 28 | May 31 | June 10 | 33 | 15 | 68 |
| 33 | W. O. E., 1.3 gm., Rotenone (10%), .5 cc., Water to 600 cc. .................... | June 11 | June 12 | June 18 | 63 | 23 | 73 |

[1] White oil emulsion.

TABLE 6. Lubricating Oils with Additional Contact Insecticides

3. Nicotine products and substitutes

| Exp. No. | Materials | Eggs laid | Eggs treated | Examined | No. dead | No. hatched | Per cent killed | Notes |
|---|---|---|---|---|---|---|---|---|
| 12 | W. O. E.,[1] 1.6 gm., Free nicotine, 1 cc., Water to 600 cc. .... | May 22 | May 25 | May 29 | 13 | 4 | 76 | Av. 86% |
| | " .... | June 17 | June 19 | June 24 | 92 | 11 | 89 | |
| 4 | W. O. E., 1.6 gm., Nic. sulf., 1 cc., Water to 600 cc. .... | May 22 | May 25 | May 29 | 15 | 3 | 83 | Av. 85% |
| 17 | Same ............. | May 28 | May 30 | June 10 | 110 | 2 | 98 | |
| 45 | W. O. E., 1.6 gm., Nic. sulf., 1 cc., Water to 600 cc. .... | July 12, 14 | July 16 | July 22 | 105 | 32 | 76 | |

[1] White oil emulsion, commercial.

TABLE 7. Lubricating Oils with Additional Contact Insecticides

4. Pine oils and miscible pine oils

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 23 | White oil emulsion, 1.3 gm., Miscible pine oil, 1 cc., Water to 600 cc. .................... | May 30 | June 3 | June 10 | 81 | 29 | 73 |
| 25 | White oil, 5 cc., Pine oil, 1 cc., Soap, 2 gm., Water to 600 cc. .................... | May 30 | June 3 | June 10 | 87 | 1 | 98 |
| 31 | " .................... | June 8, 9 | June 11 | June 18 | 52 | 1 | 98 |
| 189 | White oil, 3 gm., Pine oil, 2 gm., Milk emulsifier, Diluted to 1% oil .................... | July 12, 14 | July 16 | July 22 | 76 | 3 | 95 |

NOTES: White oil used had viscosity of 90 sec. No. 23, a commercial emulsion; Nos. 25, 31, and 189, laboratory made emulsions. Pine oil—steam distilled, straw color.

TABLE 8. Lubricating Oils with Additional Contact Insecticides

5. Oleoresin capsicum

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 32 | 90 visc. white oil, 5 gm., Ol. cap., 1 gm., Water to 600 cc., Soap, 2 gm. .................... | June 8–9 | June 11 | June 18 | 32 | 3 | 91 |
| 37a 37b | 90 visc. white oil, 3 gm., Ol. cap., 5 cc., Soap, 2 gm., Water to 600 cc. .................... | June 15–16 | June 17 | June 24 | 197 | 19 | 91 |

TABLE 9. MISCELLANEOUS MATERIALS

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 6 | Free nic., .2 cc., Soap, 2.0 gm., Water to 200 cc. | May 25 | May 28 | May 31 | 6 | 10 | 37 |
| 8 | Penetrol, 1 cc., Water to 200 cc. | May 26 | May 28 | May 31 | 2 | 20 | 9 |
| 12 | Dipyridils, .5 cc., Soap, 1.0 gm., Water to 200 cc. | May 27 | May 29 | June 3 | 1 | 13 | 7 |
| 14 | Miscible pine oil, 1 cc., Water to 100 cc. | May 27 | May 29 | June 3 | 1 | 12 | 7 |
| 15 | Miscible pine oil, 1 cc., Water to 100 cc. | May 26 | May 29 | June 3 | 1 | 12 | 7 |

TABLE 10. OLEORESIN CAPSICUM EMULSION

| Exp. No. | Materials | Eggs laid | Eggs treated | Eggs examined | No. dead | No. hatched | Per cent killed |
|---|---|---|---|---|---|---|---|
| 26 | Ol. cap., 1 cc., Soap, 1 gm., Water to 100 cc. | June 1, 2 | June 3 | June 12 | 44 | 11 | 80 |
| 28 | Ol. cap., 1 cc., Soap, 2 gm., Water to 500 cc. | May 31 June 3, 4 | June 5 | June 14 | 21 | 34 | 38 |
| 29 | Ol. cap., 1 cc., Soap, 1 gm., Water to 100 cc. | June 7 | June 11 | June 15 | 77 | 20 | 79 |

TABLE 11. ROTENONE

| Exp. No. | Materials | Eggs laid | Eggs treated | Examined | No. dead | No. hatched | Per cent killed | Notes |
|---|---|---|---|---|---|---|---|---|
| 40 | Rotenone (10%), 1 cc., Syrup, 2 gm., Water to 100 cc. .... | June 16, 17 | June 20 | June 26 | 24 | 7 | 77 | Probable efficiency about 93% on account of larval mortality after hatching |
| 41 | Rotenone (5%), 1 cc., Syrup, 2 gm., Water to 100 cc. .... | | June 28 | June 29 | 90 | 75 | 54 | 13 larvae found dead on leaves, bringing actual kill to about 61% |

## Control of Larvae

Except in the earlier instars, the larva of the Oriental peach moth is very difficult to kill. Older larvae will pass through almost any poison barrier short of metallic arsenic or arsenic pentoxide, so that from a practical standpoint the older larvae are invulnerable. The newly-hatched larvae are, on the other hand, more susceptible and should be, in theory at least, easily checked. The use of mechanical barriers such as lime and talcum powder depend on the fact that particles of these materials adhere to the surface of the newly-hatched larva and cause it to drop from the tree. Experiments with very young larvae placed on peaches dusted with different materials show that 90-10 arsenate sulfur dust, various fluosilicates and fluorides and impregnated dusts containing pyrethrum and eight per cent dipyridyl sulfate have considerable effect in preventing entrance. One of the most striking results was obtained with a special pyrethrum dust which apparently killed all larvae coming in contact with it. Not much is known of the costs of some of these materials and they have not as yet been used in field experiments. The results are shown in Table 12.

Control of hibernating larvae after spinning would be desirable if such could be accomplished economically without harm to the tree. During 1929, preliminary tests were made with hibernating larvae in paper cells that were treated with a number of materials. These tests show good killing power for certain emulsions containing 20-30 per cent pine oil in emulsified form, but this is probably too much oil for the ordinary peach tree to withstand. These results are shown in Table 13. In this connection several of the constituents of pine oil were tried and showed considerable action for limonene and terpineol, but very little for dipentene and pinene. See Table 15. Following this clue, sweet orange oil containing considerable limonene was tried and showed again considerable killing power. Our tests also demonstrate that pure gasoline or kerosene are highly destructive to larvae spun in paper cells. In addition to these, several tar acid oils were used upon larvae spun on pear branches, with fair results at 3 per cent. Experiments by Ross (55) indicate that 10 to 15 per cent tar acid oils are necessary to kill the over-wintering larvae, and the above results seem to substantiate this. Doubtless a higher percentage of crescylic acid would increase the kill to the figures he obtained.

TABLE 12. TESTS OF VARIOUS INSECTICIDES TO POISON OR PREVENT ENTRANCE OF THE NEWLY HATCHED LARVAE OF THE PEACH MOTH

| No. larvae or eggs | Number of tests | Average per cent entered | Materials used and formulae |
|---|---|---|---|
| | | | Arsenicals |
| 70 | 4 | 4.2 | 90–10 sulphur-arsenate dust |
| | | | Fluosilicates and Fluorides |
| 31 | 2 | 6 | Cal. fluosilicate 1926 product |
| 45 | 3 | 6 | Magnesium fluoride pure |
| 10 | 1 | 10 | Sodium fluosilicate—lime dust, 1 part—4 parts lime |
| 93 | 1 | 25 (10–18%)[1] | Sodium fluosilicate—lime dust, 1 part—10 parts lime |
| | | | Hydrated Lime |
| 42 | 1 | 73 | Pure hydrated lime dust |
| 32 | 2 | 36 | Pure hydrated lime dust |
| | | | Talc Dust, Fibrous |
| 41 | 1 | 51 (41)[1] | Pure talc dust |
| 64 | 1 | 62 | Pure talc dust |
| | | | Dipyridyl Sulphate Dusts |
| 43 | 1 | 16 (6)[1] | 8% dipyridyl sulfate in an inert carrier |
| 47 | 1 | 23 (0)[1] | 8% dipyridyl sulfate in an inert carrier |
| 22 | 1 | 0 | 8% dipyridyl sulfate in an inert carrier |
| 23 | 1 | 69 | 1 gm. dipyridyl sulfate, 30 gms. lime, 600 cc. water—sprayed |
| | | | Pyrethrum Dust |
| 23 | 1 | 0 | 50% pyrethrum extract, 20 dead larvae found in stem ends |
| 23 | 1 | 0 | 23–30% pyrethrum extract, 16 dead in stem ends |
| 35 | 3 | 54.2 | None |
| 12 | 1 | 100 | " |
| 10 | 1 | 90 | " |
| 5 | 1 | 80 | " |
| 41 | 1 | 90 | " |
| 11 | 1 | 57 | " |
| 32 | 1 | 59 | " |
| 18 | 1 | 50 | " |
| 199 | 10 | 56 | |

[1] Actual percentage entered after deducting the infestation in the peaches in the beginning. Ripe or nearly ripe peaches were used and it was impossible to obtain fruit entirely free of worms. Percentage deducted represents infestation of a representative sample. Experiments all conducted by placing eggs cut from leaves in the stem ends of dusted or sprayed fruit.

TABLE 13. EXPERIMENTS IN KILLING THE OVERWINTERING LARVAE OF THE ORIENTAL PEACH MOTH, 1929

Miscible Pine Oils and Pine Oil Emulsions

| Exp. No. | Material | Dates | Per cent killed | Notes |
|---|---|---|---|---|
| 1 | Miscible[1] pine oil, 50% emulsion | April 10–15 | 100 | |
| 2 | Miscible[1] pine oil, 33% emulsion | April 10–15 | 100 | |
| 3 | Miscible[1] pine oil, 20% emulsion | April 10–15 | 88 | |
| 4 | Miscible[1] pine oil, 15% emulsion | April 17–22 | 66 | |
| 5 | Miscible[1] pine oil, 10% emulsion | April 10–June 21 | 66 | |
| 6 | Miscible[1] pine oil, 10% emulsion | May 20–May 25 | 92 | Different stock |
| 7 | Sol. pine oil, 20% emulsion | April 24–29 | 86 | |
| 8 | Form. 87, 20% pine oil | April 22–26 | 88 | |
| 9 | Form. 87, 20% pine oil | April 27–May 3 | 100 | |
| 10 | Form. 88, 10% pine oil | April 22–26 | 00 | |
| 11 | Form. 74, 3% pine oil | Feb. 25–June 21 | 50 | |
| 12 | Check, no treatment | Feb. 25–June 25 | 00 | |
| 13 | Form. 93, 2.5% pine oil plus pyrethrum 10% | May 6–June 21 | 100 | 9 pupae in this lot; 4 dead; 4 larvae—all dead |
| 14 | Form. 93, 10% | May 17–June 25 | 100 | |
| 15 | Form. 93, 5% | May 17–June 24 | 97 | |
| 15a | Form. 93, 5% | May 17–June 25 | 100 | |

[1] NOTES: Miscible pine oil at 20 per cent sprayed on two peach trees at the Mount Carmel farm on April 23 after buds had reached pink. Many buds were killed but new growths started nicely on May 3.

The method used consisted of dipping the larvæ, spun in paper cells, in each material, blotting off the excess liquid and removing to the insectary where they were kept in open containers.

TABLE 14. MISCIBLE KEROSENE AND COMBINATIONS

| Exp. No. | Material | Dates | Per cent killed | Notes |
|---|---|---|---|---|
| 16 | Miscible kerosene 5%, naphthalene .1% | April 12–22 | 9 | Pupae |
| 17 | Miscible kerosene 10% | April 12–June 21 | 00 | |
| 18 | Miscible kerosene 15% | April 17–June 24 | 44 | 2 pupae |
| 19 | Miscible kerosene 10%, naphthalene .2% | April 12–June 21 | 50 | No pupae |
| 20 | Miscible kerosene 10%, ethyl acetate .1% | April 17–June 24 | 9 | |
| 21 | Miscible kerosene 10%, carbon disulfide .1% | April 17–June 24 | 0 | |
| 22 | Miscible kerosene 10%, beta-naphthol .1% | April 10–June 15 | 0 | No pupae |
| 23 | Miscible kerosene 10%, naphthalene 1.0% | April 29–June 24 | 22 | Pupae |

TABLE 15. EXPERIMENTS IN KILLING THE OVERWINTERING LARVAE OF THE ORIENTAL PEACH MOTH WITH VARIOUS SUBSTANCES, 1929

Mineral Oils and Combinations

| Exp. No. | Material | Dates | Per cent killed | Notes |
|---|---|---|---|---|
| 24 | Gasoline 80%, pine oil 20% | Feb. 25–June 21 | 100 | |
| 25 | Gasoline 50%, pine oil 50% | Feb. 13–April 10 | 100 | |
| | | Feb. 25–April 10 | | |
| 26 | Gasoline, pure | Feb. 25–April 10 | 91 | |
| 27 | Kerosene (best grade), pure | May 5–June 24 | 100 | 8 pupae in this lot |
| 28 | Fuel oil | Feb. 25–April 10 | 50 | |
| 29 | Kerosene | Feb. 25–April 10 | 100 | |
| 30 | Kerosene 50%, fish oil 50% | Feb. 11–June 24 | 70 | |
| 31 | Same, emulsified and diluted to 41% oil | Feb. 11–June 24 | 62 | |
| 32 | Check, no treatment | | 00 | |

TABLE 16. EFFECT OF SWEET ORANGE OIL AND VARIOUS PINE OIL CONSTITUENTS ON THE OVERWINTERING LARVAE, 1929-1930

| Materials | Per cent oil in diluted emulsion | Date | No. larvae or pupae | Per cent dead |
|---|---|---|---|---|
| Check, no treatment ... | .. | 1929 | 5 larvae | 0 |
| | | 1930 | 18 larvae | 5 |
| Soap 2% ............ | .. | 1929 | 21 pupae | 21 |
| | | 1930 | 10 larvae | 20 |
| Dipentene ............ | 10 | 1929 | 86 pupae | 1 |
| Soap 2% ............ | 9 | 1930 | 29 larvae | 17 |
| Pinene ............... | 10 | 1929 | 23 pupae | 27 |
| Soap 2% ............ | 9 | 1930 | 28 larvae | 42 |
| Sweet orange oil ...... | 10 | 1929 | 4 larvae | 100 |
| Soap 2% ............ | 9 | 1930 | 26 larvae | 88 |
| | 10 | 1929 | 16 pupae | 100 |
| Terpineol ............ | 10 | 1929 | 105 larvae | 97 |
| Soap 2% ............ | 9 | 1930 | 32 larvae | 90 |
| d—Limonene .......... | 10 | 1929 | 14 larvae | 100 |
| Soap 2% ............ | 10 | 1929 | 66 pupae | 98 |
| | 9 | 1930 | 32 larvae | 100 |

NOTES: All tests were made with larvæ or pupæ in paper cells; 1929 treated May 20-29, examined June 21; 1930 treated Feb. 12, examined Feb. 20. Terpineol used at 10 per cent strength on peach foilage burned severely, limonene and pinene burned slightly, and orange oil and dipentene even less.

## Control of the Moth

Two methods are available for control of the moth, namely, poisoning and repellent action to prevent egg laying. An attempt to poison adult moths was made in 1929 by adding rotenone to syrup and spraying it on leaves within oviposition cages. The results obtained are shown in Table 17 and indicate a decided reduction in number of eggs. In only one of the tests was it apparent that any poison was taken by the moths themselves. Our repellent tests have been confined to cage and small field tests; the field tests of 1928 with alpha-naphthylamine reversed results obtained in cage tests. Field technique with these materials has not yet been perfected, so that further discussion of results is not advisable at this time. The main difficulty with most repellents lies in their volatility, which causes them to disappear from the tree within a short period. Doctor Lipp, of the United States Department of Agriculture, has done much work with repellents and has devised a means for testing materials of this sort. In laboratory tests he found bone oil and alpha-naphthylamine very efficient (34).

TABLE 17. TESTS IN PREVENTION OF EGG-LAYING BY APPLICATIONS OF ROTENONE AND SYRUP

| Dates | Notes on experiments | No. eggs obtained on— Treated | Untreated |
|---|---|---|---|
| July 19–24 | Large number of moths in cage about 6″ square, two shoots sprayed with rotenone (1.5 cc. 10% in acetone) in 200 cc. water, 2 gm. refiners' syrup added, two shoots untreated in opposite corners of cage. Moths crowded probably accounting for the fairly large number on treated shoots. | 763 | 1719 |
| June 13 | 50 moths in two different cages of same size, one with peach shoots treated with 1 cc. 10% acetone solution plus 1 gm. honey in 100 cc. water. June 17, three moths or 6% were alive in cage with treated shoots; 19, or approximately 50%, were alive in untreated ................ | 76 | 288 |
| June 18 | Same as on June 13. June 24, 6 moths were alive in treated cage, 12 in check ... | 15 | 203 |
| June 24 | Same as June 18 and 13, using syrup instead of honey, about 25 moths in each cage. June 29, three alive in both cages.. | 0 | 7 |
| | Total ............................ | 854 | 2217 |

## FIELD CONTROLS

### History

Shortly after the discovery of the moth in 1917, an investigation of controls in the District of Columbia, Maryland and Virginia disclosed the fact that the ordinary arsenical lime sulfur sprays (self-boiled) were not adequate, because of injury to the tree and the several brooded nature of the pest. Nicotine sulfate was next advocated by Virginia (61) and taken up in New Jersey. By this means about 10 per cent reduction in injury may be obtained, but this is not sufficient and it is considered too expensive by orchardists for the results obtained. Turning now to other means, Ohio (69) studied the use of hydrated lime in large quantities, but this material has not been entirely successful and has not worked well in our field experiments. Likewise, talc dust has been used in New Jersey (10) with considerable promise, but has not yet given satisfactory results in Connecticut. Both this and lime sprays should, however, be considered as still in the experimental stage.

It was found also that pans containing fermented molasses attracted many moths, so this too was used as a control, with little or no success to date. The reason for this failure lies probably in the fact that only a small percentage of the moths in an orchard are captured by this method. For example, bait pans hung in a cage provided with moths caught very few and eggs were deposited within a few feet of the baits. Stear (58) reports 4-30 per cent catch of marked moths liberated in an orchard where pans were maintained. Much work has been done towards perfecting baits and containers by Frost (18, 19) and Peterson (42, 43) and it has been shown by these workers that enamel or protected pans containing one-half gallon or more give the best results. The best bait appears to be a cheap grade of molasses or refiners' syrup diluted one part in 20 parts of water. For our conditions a refiners' syrup has given good results. Bait pans, in spite of their failure to date in giving satisfactory control, are useful in indicating the extent of the different broods and in telling the orchardist whether moths are abundant in his orchard.

## Control Experiments in Connecticut

Our first experiments in control of the Oriental peach moth in Connecticut consisted of various nicotine and arsenical applications, which gave the results shown in Table 18. These were conducted in a large orchard near Greenwich in southwestern Connecticut. The spraying equipment is seen in Plate XII. The fruit was graded from exterior examination, but a representative number from each plot was cut open, and the number missed on the first examination was then estimated. The percentages appear in the last column.

TABLE 18. RESULTS OF SPRAY EXPERIMENTS TO CONTROL THE ORIENTAL PEACH MOTH AT CONYERS FARM, 1924. VARIETY, BELLE OF GEORGIA

| Block | Treatment | Good | Infested | Per cent | Per cent infested based on cut fruit |
|---|---|---|---|---|---|
| 1 | Fungicide only, 2 sprays .. | 3237 | 393 | 10.8 | 23 |
| 2 | Five sprays with nicotine sulfate. Two of these with arsenate .......... | 2528 | 190 | 6.9 | 14 |
| 3 | Fungicide plus lead arsenate .................. | 3539 | 408 | 10.3 | .. |
| 4 | Five dusts containing nicotine, 2 with arsenate .... | 1847 | ·63 | 3.2 | 11 |

This work was continued in 1925 in two different orchards and complete records were kept of the fruit examined, all being cut open. These figures show that that old or second brood injury is about one-third or one-fourth the total injuries, but that none of the scheduled applications were especially successful. Table 19 shows results obtained in the Barnes orchard at Wallingford, and Table 20 those at Conyers Farm in Greenwich.

TABLE 19. RESULTS OF SPRAY EXPERIMENTS TO CONTROL THE ORIENTAL PEACH MOTH, BARNES ORCHARD, 1925. VARIETY, ELBERTA

| Block No. | Treatment | Total fruits | Per cent infested |
|---|---|---|---|
| 1 | 90–10 dust, July 15, Aug. 14 | 824 | 37.8 |
| 2 | Nicotine dust, July 15, July 30, Aug. 14 | 755 | 27.9 |
| 3 | Check | 439 | 46.7 |

Table 19 shows a considerable reduction for nicotine dust. The results obtained at Conyers Farm contradict this, although in the previous season they were more favorable. Thus in 1924 we obtained a reduction of 12 per cent by this means, whereas in 1925, after shifting the block to a more unfavorable location, no reduction was obtained. Here the most favorable treatment was found to be nicotine sprays, which netted a reduction of 12 per cent. It becomes apparent, therefore, that nicotine sulfate, either in the form of a spray or dust, will reduce injury from the peach moth, for in spite of one failure, there are three successes in our field experiments. The amount of injury reduction varied from 12 per cent with a 23 per cent infestation to about 18 per cent with a total check infestation of 46.7 per cent. In the Barnes orchard, however, this left 27.9 per cent infested fruit in the nicotine dusted plot, which is too much from a commercial standpoint.

TABLE 20. RESULTS OF SPRAY EXPERIMENTS TO CONTROL THE ORIENTAL PEACH MOTH AT CONYERS FARM, 1925. VARIETY, BELLE OF GEORGIA

| Block No. | Treatment | Total fruits | Per cent injured |
|---|---|---|---|
| 1 | Nicotine dust (2.7%) July 13, July 29, Aug. 10 | 1964 | 22.9 |
| 2 | 90-10 sulfur arsenate dust, July 13, Aug. 10 | 1932 | 15.5 |
| 3 | Check | 1924 | 21.5 |
| 4 | Nicotine sulfate spray, July 13, July 29, Aug. 10, Aug. 20 | 1883 | 10.5 |

In 1927, a block of about 50 trees at Wallingford was sprayed twice in July with sodium fluosilicate, glue, lime and water, followed by two applications of white oil emulsion, to which was added nicotine sulfate half strength and oil of citronella. The following results were obtained:

TABLE 21. RESULTS OF SPRAYING TO CONTROL THE ORIENTAL PEACH MOTH AT WALLINGFORD, 1927. VARIETY, ELBERTA

| Treatment | Total fruits | Per cent old injury | Per cent new injury | Total per cent injured |
|---|---|---|---|---|
| Sprayed | 702 | 3.9 | 5.3 | 9.2 |
| Check—Sulfur dust only | 747 | 8.3 | 6.2 | 14.5 |

It may be added that the sprayed plot here was in an unfavorable location, indicating that the reduction in old and new injury does not necessarily show the value of the treatments. There is some reduction both in old and new injury, however. In 1929, after a lapse of one year, field work was again undertaken, due to the development of talc dusts and heavy lime sprays in the meantime. Also it was thought advisable to test oils with additional materials as controls. An orchard of about four acres was leased at Mount Carmel and work conducted throughout the season. The following results were obtained after cutting all fruit from five selected trees.

TABLE 22. RESULTS OF SPRAYING TO CONTROL THE ORIENTAL PEACH MOTH AT MOUNT CARMEL, 1929. VARIETY, ELBERTA

| Block No. | Treatment | Total fruits | Per cent injured fruit | Per cent fruit injury to check trees in each block |
|---|---|---|---|---|
| 1 | Talc dust, 10 applications .... | 1402 | 28.2 | 25.2 |
| 2 | White oil emulsion,[1] light, with nicotine sulfate, 5 sprays in August and September at weekly intervals .......... | 768 | 16.0 | 28.0 |
| 3 | W. O. E.,[2] concentrate with pyrethrum soap, 5 sprays in August and September at weekly intervals .......... | 535 | 19.4 | 19.5 |
| 4 | Lime, 5 applications in June and July at 10-day intervals .... | 1569 | 19.9 | 20.2 |
| 5 | Check, no treatment ......... | 1420 | 22.2 | ... |

In addition to the figures given above, an experiment was carried on in a small plot of about twenty trees on the Experiment Station farm, using a commercial white oil emulsion in comparison with no treatment. This is shown in Table 23.

TABLE 23. EXPERIMENT TO CONTROL THE ORIENTAL PEACH MOTH, STATION FARM, 1929. VARIETY, ELBERTA

| Treatment | Total fruits | Per cent injured |
|---|---|---|
| W. O. E. conc. 1%, .8% oil, 4 sprays in August, 1 in September ............................ | 658 | 7 |
| Check, no treatment ........................ | 699 | 20 |

Several quince trees were also sprayed with white oil emulsion (concentrate) during August and September, 1929, at weekly intervals. These fruits were picked about October 1, and the number of exit holes counted on the sprayed and the unsprayed fruit. There were fewer such marks on the sprayed quinces, although the amount of infested fruit was about the same. In

[1] Commercial preparation, 1.5 per cent oil in diluted spray. Viscositv of oil 50 sec.
[2] Commercial preparation, .8 per cent oil in diluted spray. Viscosity of oil 108 sec.

1928 two orchardists sprayed and dusted their quinces (sulfur-arsenate 90-10 dust and lead arsenate in combination with dry mix) at 10 days intervals in August. The treatments apparently gave no control. In the case of quinces there is the whole of September when reinfestation might occur, but it seems inadvisable with poison sprays to continue applications too late, on account of harmful residue that may remain at harvest. Oil sprays might possibly be continued except for the expense which would (at present costs), after many applications easily consume whatever profit there is in the fruit and certainly would not pay unless their effectiveness is considerably increased.

In 1926 and 1927 bait pans were used in a large orchard in Wallingford and the fruit scored at harvest by cutting open a representative number. Results are given in Table 24.

TABLE 24. TESTS WITH BAIT PANS AS A CONTROL FOR THE ORIENTAL PEACH MOTH, 1926 AND 1927. VARIETY, ELBERTA

| Treatment[1] | Total fruits | Per cent injured |
|---|---|---|
| 1927 | | |
| Pail in every tree | 775 | 13.9 |
| Check, dust only | 747 | 14.5 |
| 1926 | | |
| Pail in every tree | 1024 | 12.7 |
| Pail in every other tree | 1370 | 9.7 |
| Check, dust only | 928 | 10.5 |

The theory of this means of control is that moths are attracted to fermenting baits, fly into the liquid and are unable to escape. When the moths are most numerous in the orchard, thousands may be caught in the pans. It is believed that the fermenting sugars are necessary and it has been proved that tin pails are not as satisfactory as enamel or glass containers, because of the reaction of the liquids on the metal. Suitable enamel pails may be purchased as low as 15 cents each and for practical purposes (determination of broods) cheap molasses can be used. This should preferably be renewed once a month and the pails kept filled with water frequently during dry periods. A dilution of one part molasses in 20 parts water with or without yeast is satisfactory.

## Control in Twigs

During 1919, the writer conducted some experiments on the grounds of the Maryland Agricultural Experiment Station for control of the Oriental peach moth in twigs. Twelve small trees were selected and every other tree sprayed with a formula con-

[1] All trees, including those with pails, were dusted several times with sulfur dust by the owner.

TABLE 25. CONTROL OF THE ORIENTAL PEACH MOTH IN TWIGS, COLLEGE PARK, MD., 1919

| Treatment | Exp. No. of tree | Number of injured shoots on following dates: May 29 | June 5 | July 5 | July 16 | Aug. 8-9 | Aug. 16 | Aug. 18 | Sept. 1 | Estimated shoots per tree | Total twigs injured |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sprayed ... | 2 | 0 | 0 | 17 | 10 | 26 | 5 | 9 | 5 | 100 | |
| | 4 | 0 | 0 | 18 | 17 | 28 | 1 | 3 | 3 | 200–300 | |
| | 6 | 0 | 2 | 15 | 8 | 21 | 2 | 0 | 0 | 100 | |
| | 8 | 1 | 2 | 11 | 11 | 9 | 1 | 3 | 6 | 200–300 | |
| | 10 | 0 | 4 | 13 | 21 | 32 | 3 | 0 | 2 | 200–300 | |
| | 12 | 3 | 7 | 12 | 4 | 6 | 0 | 0 | 0 | 70 | |
| Totals.. | | 4 | 15 | 86 | 77 | 152 | 11 | 15 | 16 | | 376 |
| Checks .... | 1 | 8 | 0 | 54 | 4 | 48 | 5 | 9 | 5 | 150–200 | |
| | 3 | 10 | 0 | 32 | 12 | 52 | 6 | 5 | 4 | 150–250 | |
| | 5 | 9 | 2 | 33 | 11 | 8 | 6 | 2 | 4 | 75 | |
| | 7 | 18 | 8 | 36 | 7 | 18 | 8 | 3 | 6 | 200–300 | |
| | 9 | 4 | 14 | 23 | 7 | 46 | 5 | 8 | 3 | 70 | |
| | 11 | 13 | 13 | 55 | 22 | 77 | 10 | 5 | 1 | 300–400 | |
| Totals.. | | 62 | 37 | 233 | 63 | 249 | 40 | 32 | 23 | | 739 |

NOTES: Dates of spray applications, May 9, May 12, May 31, June 21, July 11, Aug. 1 and Aug. 8. Sprays on May 9 and Aug. 1 contained arsenate of lead; others did not.

taining self-boiled lime sulfur, calcium arsenate, calcium caseinate and nicotine sulfate. The arsenate was used in two of the applications and the number of injured twigs counted regularly and tagged. The results are shown in Table 25. Since these figures have not been published, they are given here, with permission of the Maryland Experiment Station.

From the data in Table 25 it was concluded that sprays should be made more frequently to obtain satisfactory control, especially since the results vary and, considered from the mathematical standpoint, are doubtfully important. There is little doubt, however, that there is some reduction in number of injured twigs. In 1929, 12 small peach trees at New Haven were divided into two plots, one of which was dusted frequently with talcum powder and the other left without treatment. Injured twigs were frequently removed, care being taken to obtain all infested shoots. The results are shown in Table 26. Both ordinary and fibrous talc dusts were employed and the results revealed more injured twigs for the ordinary talc and slightly less for the fibrous talc. This corresponds in general with our field experiment with fruit, where there was no gain in sound fruit from the use of talc. Weather conditions were favorable for the tests, since there was very little rainfall.

TABLE 26. EFFECT OF DUSTING WITH TALC TO PREVENT ENTRY OF LARVAE IN TWIGS

| Kind of talc | Dates treated | Date injured twigs removed | Number from dusted trees | Number from check trees |
|---|---|---|---|---|
| Ordinary | June 14 | June 18 | 17 | 19 |
| | June 18 | June 20 | 29 | 20 |
| | June 26 | June 24 | 25 | 26 |
| | June 29 | June 26 | 16 | 15 |
| | | June 28 | 16 | 11 |
| | | July 1 | 16 | 9 |
| Totals | | | 119 | 100 |
| Fibrous talc | July 3 | July 3 | 5 | 4 |
| | July 6 | July 6 | 4 | 10 |
| | July 12 | July 9 | 19 | 24 |
| | July 16 | July 11 | 9 | 13 |
| | | July 13 | 25 | 15 |
| | | July 15 | 7 | 9 |
| | | July 19 | 12 | 12 |
| Totals | | | 81 | 87 |
| Totals for both kinds of talc | | | 200 | 187 |

## Cultivation

Complete thorough cultivation for the peach moth has been practiced for a number of years by Connecticut growers. The best results were obtained apparently in the Barnes Orchard at Wallingford, where all ground was broken or plowed in the fall, with frequent cultivation in spring and summer up to August. There is little doubt that some good has been done by this control measure, but from observations in other orchards, where the infestation is heavy, it is apparent that such methods do not afford complete or, in some cases, even satisfactory relief. Thus in the Rogers orchard, one of the heaviest infestations yet seen in Connecticut followed a year of intensive complete cultivation. There are orchards, too, that cannot be completely cultivated, being located on hillsides where complete cultivation would do more harm than good because of erosion. On the other hand, some cultivation of peaches appears to be essential in peach culture in Connecticut and whether it is complete or partial is determined by the nature of the land and preference of the owner.

## SUMMARY OF CONTROLS

1. Thus far it has been seen that arsenicals as controls are ineffective, as well as dangerous on peach trees, if applied repeatedly.
2. Nicotine sprays or dusts reduce the infestation considerably but not enough.
3. Lime sprays and talc dusts did not afford protection in our orchard in 1929.
4. White oil emulsions gave some reduction but not enough.
5. White oil emulsions with additional materials have not materially increased effectiveness in the field.
6. Materials applied against the overwintering larvae, while apparently effective in laboratory tests, have not yet been proved safe or effective in field practice.
7. Repellents are still in the experimental stage and have not yet been proved of value in field control.
8. Bait pans have not been effective so far, apparently because of the large number of moths in an infested orchard and the relatively small number caught by such means.
9. Cultivation recommended for the last few years has not given the desired relief in heavily infested orchards. There is no doubt, however, that it destroys many larvae and should therefore be continued in the general scheme of control.
10. Paradichlorobenzene will kill most of the larvae that are reached, but cannot be depended upon for complete control; and furthermore, is usually applied before the majority of the larvae spin.

## RECOMMENDATIONS

The present status of the peach moth in Connecticut justifies the following recommendations. It should be recognized, of course, that only partial control will result from these measures, but we believe them advisable in view of the seriousness of the situation.

1. Cultivation: complete to trunks of trees, spring cultivation to be complete by May 15, preferably May 1; depth, four inches.

2. Prompt destruction of cull fruit and screening of packing sheds to prevent escape of moths. The fruit shed should be closed until the middle of July. Care or destruction of containers where larvae have spun.

## PARASITES

In considering the damage brought about by the Oriental peach moth, it has been observed that the period of increase and decrease in certain orchards has followed a definite cycle. Beginning with a small infestation of perhaps 10 to 15 per cent, where it may remain for two or three years, it may then jump to 50 per cent or even higher, and stay there several years before it begins to decline. In some orchards the period of severe damage has persisted for three or even four years, causing great monetary loss. Connected with periods of decline there has been apparent in several different orchards a decided increase in parasites, particularly the more common *Macrocentrus ancylivora*. In other localities *Trichogramma minuta* has been observed throughout the season. *Glypta rufiscutellaris* has been abundant in some years, and in one orchard a considerable number of *Eubadizon* sp. was found. A list of about 50 parasites has been compiled by Stearns (80) and there are probably others not yet recorded. Thirty parasites are listed below from Connecticut and neighboring states.

| Parasite | Distribution | Prevalence in Connecticut |
|---|---|---|
| 1. *Macrocentrus ancylivora* Roh. | New Jersey, Pennsylvania, Connecticut, Maryland, Virginia, Ohio, New York | Present in considerable abundance in some orchards. |
| 2. *Macrocentrus delicatus* Cr. | New Jersey, Connecticut, probably others | |
| 3. *Glypta rufiscutellaris* Cr. | New Jersey, Connecticut, Pennsylvania, Maryland, Virginia, Georgia, Ontario | Fairly common in Connecticut. |
| 4. *Eubadizon* sp. | Connecticut, Georgia, Ontario, Virginia | Present in one orchard in considerable numbers. |
| 5. *Trichogramma minuta* Riley | New Jersey, Virginia, Maryland, Connecticut | Very abundant in some orchards. |

The following parasites from nearby states have not been observed in Connecticut or are rare in our orchards:

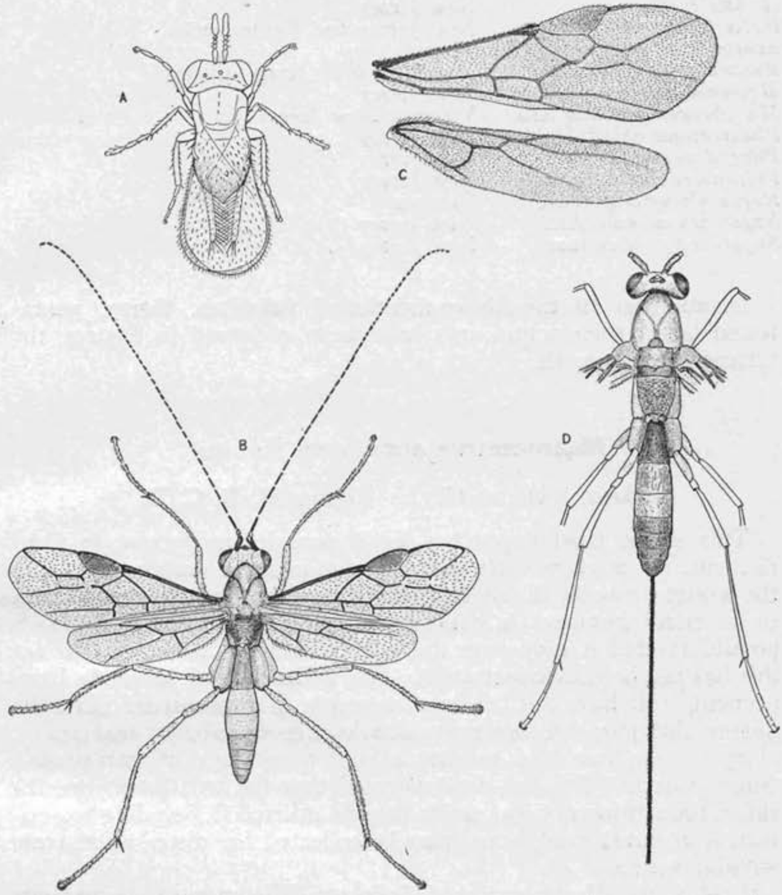


FIGURE 34. Parasites of the Oriental peach moth. A, an egg parasite, *Trichogramma minuta* Riley; B, C, D, *Macrocentrus ancylivora* Rohwer; B, male; C, wings of female; D, body of female. All much enlarged.

| | | |
|---|---|---|
| 6. | *Ascogaster carpocapsae* | Virginia, Maryland, New Jersey, Pennsylvania |
| 7. | *Cremastus minor* Cush. | New Jersey |
| 8. | *Cremastus forbesii* Weed. | New Jersey |
| 9. | *Cremastus* sp. | New Jersey |
| 10. | *Aenoplex betulaecola* Ash. | New Jersey, Pennsylvania |
| 11. | *Allocota thyridopterigis* Riley | Pennsylvania |
| 12. | *Calliephialtes grapholithae* Cresson | New Jersey, Pennsylvania |
| 13. | *Calliephialtes* sp. | New Jersey |
| 14. | *Centeterus ineptifrons* Gahan | New Jersey, Pennsylvania, Virginia (in quinces) |
| 15. | *Cryptus vinctus* Say. | New Jersey |
| 16. | *Ephialtes aequalis* Prov. | Virginia |
| 17. | *Epiurus indagator* Cress. | New Jersey |
| 18. | *Goniozus* sp. | Virginia |

| | | |
|---|---|---|
| 19. | *Hemiteles* sp. | New Jersey |
| 20. | *Itoplectis conquisitor* Say. | New Jersey and Pennsylvania |
| 21. | *Leucodesmia nigriventris* Gir. | Virginia |
| 22. | *Euzanillia variabilis* Coq. | Maryland, New Jersey, Georgia |
| 23. | *Meteorus hyphantria* Riley | New Jersey |
| 24. | *Microbracon gelechiae* Ash. | Virginia, New Jersey |
| 25. | *Phanerotoma tibialis* Hald. | New Jersey |
| 26. | *Phygadeum* sp. | New Jersey |
| 27. | *Pristomerus ocellatus* Cush. | New Jersey |
| 28. | *Rogas platypterigis* Ash. | Virginia |
| 29. | *Sagaritis consimilis* Ash. | New Jersey |
| 30. | *Sagaritis patsuiketorum* | New Jersey |

In addition to the above-mentioned parasites, thrips, pentatomid bugs, spiders and ants have been observed to destroy the Oriental peach moth.

## **Macrocentrus ancylivora** Rohwer

Plates VIII, a, IX, b; Figure 34, B, C, D.

This is the most important larval parasite at present in Connecticut. It appears early in the season in small numbers, passing the winter probably in late twig-infesting larvae of the peach moth, or in small numbers in fruit-infesting larvae. There is also a possibility that it may pass the winter in other hosts, but so far this has not been demonstrated. Fall collections of larvae in Connecticut fruit have not produced a single Macrocentrus. In New Jersey this parasite, however, attacks the strawberry leaf roller, *Ancylis comptana,* and reaches a high percentage of parasitism.[1] Since Stearns (85) has demonstrated that the two forms are the same, the strawberry leaf roller may be utilized in breeding experiments, or parasitized larvae may be collected for distribution from suitable sources.

Briefly, the life history is as follows: The eggs of the parasite are laid in the body of the peach moth larva of all stages. "Macros" will also develop in all stages of the leaf roller. Fink (79) states that the incubation period lasts from 3-13 days and that the number of eggs found in the female ovaries varies, the minimum contained being 384 and the maximum 786. If all eggs develop and are successfully deposited, each one in a single peach moth larva, the normal increase would be from two to seven times as fast as that of the peach moth, since the period of development is essentially the same as that of its host. That is to say, development from egg to adult requires approximately the same length of time as the peach moth and the only chance for this species to

[1] It has also been reared by us from Connecticut leaf rollers.

gain on its host lies in the greater egg-laying powers of the parasite.

Under normal conditions many "Macro" larvae will emerge from hibernating larvae in October, leaving few to be carried over until the following year. Those passing the winter do so in the larval stage inside the host, spinning and pupating the following spring. Development will naturally be slower in fall and spring than in midsummer, so that the life cycle as stated will not apply at these periods.

Of all larval parasites collected in nine orchards in 1929, 65 per cent were Macrocentrus, which shows the relative importance of this species. Less extensive collecting in 1928 showed relatively few. "Macros" first began to be noticed in Connecticut in the orchard of the Barnes Orchard and Nursery Company at Wallingford in 1926, when a decided reduction in fruit injury occurred. They were again noticed in 1927 and reduction in injury attributed in part to their presence together with cultivation that was thoroughly done. Further observation at Southington in 1928 and 1929, however, led to the conclusion that cultivation had not reduced the infestation materially. At East Wallingford in the Young orchard, there was a decided drop in infested fruit for the first time in 1929 and the "Macros" were collected in considerable numbers in this orchard in June. It seems logical to attribute some beneficial action to the parasites present in the orchard, and in all probability the Macrocentrus species have had much to do with it.

According to Stearns (80), as well as our own work in two different localities in 1929, the parasitism of Macrocentrus rises sharply as the number of twig-infesting larvae decreases and more peach moth larvae enter the fruit. This will account in large measure for increased percentages of parasitism in late summer and should not necessarily be taken to indicate greatly increased parasitism. We believe an early parasitism, 40 to 50 per cent, reaching its height in the second brood occurring in July, is needed to check the peach moth and that it is highly desirable to supplement its work with another parasite or parasites which will work better on larvae in the fruit or in the egg. The following table gives results of liberations of "Macros" in 1929.

### Introduction of Macrocentrus

In 1929 about 1,000 "Macros" were placed in an orchard in Southington and approximately 300 in Farmington, where no parasites were observed. These came from the laboratory of the United States Bureau of Entomology, at Moorestown, N. J., in wooden boxes containing 100 to 400 adults. Others were brought back by the writer in strawberry leaf rollers from which the para-

TABLE 27. RESULTS OF MACROCENTRUS LIBERATIONS, 1929

| Source of twigs | Date of collection | Moths obtained | Macro-centrus obtained | Larvae (alive) | Per cent parasites to date | Notes |
|---|---|---|---|---|---|---|
| Southington, Rogers | June 10 | 56 | 1 | 0 | 1.7 | General collections in vicinity of Plots 1 and 2 |
| Rogers | July 2 | 11 | 4 | 0 | 26 | General collections in vicinity of Plots 1 and 2 |
| Rogers | July 15 | 37 | 10 | 0 | 21 | General collections in vicinity of Plots 1 and 2 |
| Rogers | Aug. 13 | 0 | 23 | 4 | 85 | General collections in vicinity of Plots 1 and 2 |
| Rogers plots 1 and 2 | Aug. 24 | 0 | 6 | 0 | 100 | |
| " plots 1 and 2 | Sept. 2 | 1 | 3 | 3 | 42 | Collected from trunks of trees |
| " plot 3 | Aug. 26 | 1 | 4 | 0 | 80 | |
| " plots 4 and 5 | Sept. 2 | 0 | 3 | 0 | 100 | |
| Southington, Rogers "Barn lot" | Aug. 13 | 2 | 40 | 10 | 77 | About 2 miles from points where parasites were liberated |
| Farmington, Root | July 15 | 50 | 0 | 0 | 00 | Collections in June also showed no parasitism |
| Root | Sept. 2 | 1 | 2 | 4 | 28 | Collections in June also showed no parasitism |

Record of Parasites Released, Southington, Rogers orchard

| Plot | Date | Males | Females | Total parasites | Notes |
|---|---|---|---|---|---|
| 1 | Aug. 13 | 72 | 54 | 126 | Counted by us |
| 2 | Aug. 15 | 88 | 81 | 169 | Counted by us |
| 3 | Aug. 22 | 400 males and females | | 400 | Not counted by us |
| 4 | Aug. 29 | 129 | 175 | 304 | |
| | | | | 999 | |

Farmington, Root orchard

| | |
|---|---|
| Aug. 15 | 10 |
| Aug. 20 | 112 |
| Aug. 26 | 200 |
| | 322 |

Total parasites released 1321

sites were subsequently bred. Both methods were successful as far as the parasites themselves were concerned. "Macros" are easily handled, and we experienced no difficulty in getting them into orchards 25 to 40 miles from the laboratory. They can no doubt be transported with ease much further. The strawberry leaf rollers were collected in New Jersey the last week of July, brought to New Haven, where the folded leaves were kept for awhile in our insectary and then put in emergence cages. Plate X, b. Some 450 parasites emerged from a total of 6,000 folded leaves. They were placed in a small mating box after emergence and transported therein direct to the orchard. Release of this lot was made in several different portions of the orchard, locations being selected where there were plenty of new growth and freshly-injured twigs. Recovery of the parasite was made in the Farmington orchard towards the latter part of the season. At the Southington orchard "Macros" were present in June, averaging 1 to 2 per cent in collections made June 10 and 17. In July it increased to 20 per cent and in August there was a further increase to 80 per cent which was shortly before parasite introduction. Collections after this date varied from 80 to 100 per cent parasitized.

### Glypta rufiscutellaris Cresson

Plate VIII, b.

This is a second larval parasite, fairly common in some years, but decreasing to negligible numbers in others. It was observed in 1928 to constitute about 70 per cent of the parasites collected on the Station grounds in New Haven, whereas in 1929 there were no Glypta taken in this locality. Just why this variation should occur is not well understood.

Not much is known of the life history in Connecticut except that the adults appear in August and September and frequently winter in the cocoons of the peach moth. From this it would appear as if there were two generations. We have not observed mating nor have we been able to get them to oviposit in larvae that infest twigs. Glypta will no doubt prove to be useful in some orchards, but it will need to be studied carefully to determine the best methods of handling, as well as the cause of fluctuations already mentioned. We have succeeded in rearing this species also from strawberry leaf rollers obtained in Connecticut.

### Trichogramma minuta Riley

Plate IX, a; Figure 34, A.

Eggs of the Oriental peach moth are parasitized by this species, the small fly inserting its eggs directly in the eggs of the peach moth. The entire life cycle of the parasite from egg to adult is passed within the egg, which is completely destroyed. Parasitism of this type is highly desirable, especially since there is no chance on the part of the peach moth to do damage before being killed. Investigations in Connecticut have revealed the presence of Trichogramma in considerable numbers in four different orchards and it doubtless occurs in others. It was found at New Haven in 1929, parasitizing eggs placed in the trees as well as eggs normally present. Table 28 gives the results of these counts:

TABLE 28. PARASITISM OF THE ORIENTAL PEACH MOTH BY TRICHOGRAMMA MINUTA

| Date | Number of eggs | Per cent of parasitism | Notes |
|---|---|---|---|
| June 21 ............ | 39 | 20 | In eggs normally present |
| June 22–25 ......... | 89 | 51 | Placed in the field in several different locations |
| June 26–28 ......... | 63 | 49 | Placed in the field in several different locations |
| July 5–8 ........... | 39 | 66 | Placed in the field in several different locations |
| July 16–18 ......... | 278 | 20 | Placed in the field in several different locations |
| Aug. 17–20 ......... | 216 | 68.9 | Placed in the field in several different locations |
| Sept. 5 ............ | 192 | 80 | Eggs normally present, collected from leaves on trees |

Parasitism of this magnitude must result in some good; it should be noted that parasitism began early and continued until harvest. At Mount Carmel parasitism was not followed throughout the season, but was observed in June to be about 15 per cent and again in September, when more than 80 per cent of the eggs were affected. An attempt was made at Southington to colonize the species with material obtained from the laboratory of the United States Bureau of Entomology, at Arlington, Mass. The parasites were obtained in grain moth eggs fastened to small pasteboard cards. These were hung in trees, using about 4,000 per tree, and the degree of parasitism was determined before and after from counts of eggs placed in the trees. These data are shown in Table 29.

The data in Table 29 indicate, but not conclusively, that there was some increase in parasitism from the liberations, but they do show that Trichogramma was working effectively about August 5. The owner noticed some reduction in injury in the vicinity of the plot on early fruit, Belle of Georgia, but not in some of the later varieties, partly because of the small crop. With the amount of larval parasitism by Macrocentrus that occurred here during August and the egg parasitism, we look for a marked decrease in

TABLE 29. RESULTS OF TRICHOGRAMMA LIBERATION AT SOUTHINGTON, CONN. PARASITES HUNG ABOUT AUGUST 1

| Eggs exposed July 20, 22 | | | | | Eggs exposed August 5-8 | | |
|---|---|---|---|---|---|---|---|
| Tree No. | Total eggs | Parasitized | % | | Total eggs | Parasitized | % |
| 1 | 120 | 0 | | Inside test plot | 18 | 3 | |
| 2 | 62 | 0 | | " | 66 | 10 | |
| 3 | 159 | 4 | | " | 58 | 1 | |
| 4 | 41 | 4 | | " | 63 | 24 | |
| 5 | 185 | 21 | | " | 201 | 6 | |
| Totals | 557 | 29 | 5 | " | 406 | 44 | 10 |
| 6 | 68 | 12 | | North of test plot | 136 | 33 | |
| 7 | 112 | 0 | | " | 103 | 38 | |
| 8 | 3 | 2 | | " | | | |
| Totals | 183 | 14 | 7 | " | 239 | 71 | 29 |
| 9 | 14 | 0 | | South of test plot | 11 | 7 | |
| 10 | 35 | 2 | | " | 31 | 15 | |
| Totals | 49 | 2 | 4 | " | 42 | 22 | 52 |
| Totals | 770 | 45 | 5 | West of test plot | 93 | 29 | |
| | | | | " | 13 | 0 | |
| | | | | " | 106 | 29 | 27 |
| | | | | East of test plot | 91 | 32 | 35 |
| | | | | Totals | 885 | 197 | 22 |

abundance of the peach moth in 1930, unless other unforeseen factors interfere.

Following the discovery of Mr. Flanders in 1927 (84) of the fact that *Trichogramma minuta* may be bred on grain moth eggs,[1] many entomologists have taken up the work. This has resulted in the development of a technique which enables one to grow them in large numbers. There are, however, a number of difficulties to be overcome. Mites, such as *Pediculoides ventricosus,* and species of the family Gamasidae or Parasitidae cause much trouble, the first destroying the grain moth by feeding on various stages, and the second by feeding on the eggs. Apparently the most satisfactory method of dealing with these pests is to heat the grain that is used before infesting it with grain moths. Some workers have used sulfur to keep down mites, while others report failure of this means because of the fact that sulfur destroys or repels the parasite Trichogramma. Various incubators (89) and other apparatus have been devised for rearing the moths, the incubators being intended to maintain the temperature at 80° F. or above and the humidity at 50 to 70 per cent. The main problem seems to

[1] *Sitotroga cerealella.*

be in maintaining grain moths in large enough quantities to produce enormous quantities of eggs and the development of laboratory technique sufficient to handle them efficiently and economically.

### Modifications of Orchard Practices to Favor Parasites

It has been suggested that various measures be taken to favor parasites in the orchard. One of these schemes involves planting strawberries in or near the orchard in order to provide strawberry leaf roller hosts for Macrocentrus after the peach moth leaves the twigs. Another such scheme involves late stimulation of occasional peach trees throughout an orchard so that twig infestations by the peach moth may continue as long as possible, thus providing means for Macrocentrus to carry over from season to season. Neither of these plans has been tested commercially or scientifically, so that no definite recommendations can be made. It would also seem from our experience that the effect of various orchard spray and dusting practices as well as cultivation should be carefully studied in relation to their effect on Trichogramma egg parasites.

### Attempt to Rear Parasites under Artificial Conditions

Following the discovery that parasites work fairly well in Connecticut and that they will survive our winters, the peach growers under the leadership of Mr. H. M. Rogers, of Southington, have asked that a laboratory for their production be organized. Consequently an emergency appropriation was secured, together with subscriptions from about 150 growers, amounting in all to about $7,000.00. With this fund work has been started, both with Trichogramma and Macrocentrus. It is too early to say much about this work other than that considerable progress has been made.

## ACKNOWLEDGMENTS

In connection with our experiments in peach moth control, the author gratefully acknowledges the help given by various orchard owners as well as temporary assistants in our department who have helped in fruit counts and spray programs. The aid received from Mr. G. A. Drew and Mr. H. B. Reed of Conyers Farm, from the Barnes Brothers of the Barnes Orchard and Nursery Company, from the Bishop Brothers of Cheshire, and from Mr. S. H. MacDonald of Wallingford is especially acknowledged. These men have made treatments at our suggestion, have supplied spray outfits and labor or have helped in other ways. Mr. J. F. Townsend has been of great assistance in field and insectary work and his labors have resulted in much expansion of the work in 1929. His work in the construction of various apparatus has been especially helpful. Mr. B. H. Walden made the photographs and deserves all credit for them. We are also greatly indebted to the Federal laboratories at Moorestown and Arlington, where we secured much valuable aid through the kindness of Dr. H. W. Allen and Mr. D. W. Jones. We are also indebted to Dr. R. C. Roark of the United States Bureau of Chemistry and Soils, who supplied a quantity of rotenone for study, and to Mr. Neely Turner for his help with various control experiments.

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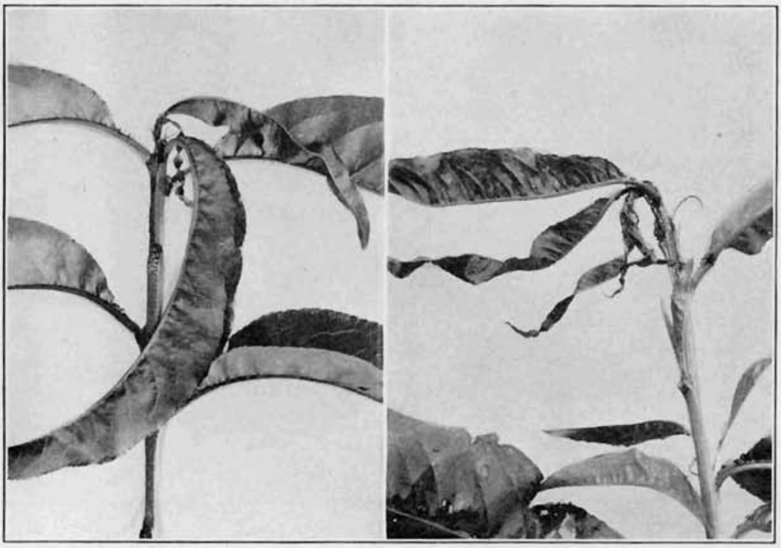
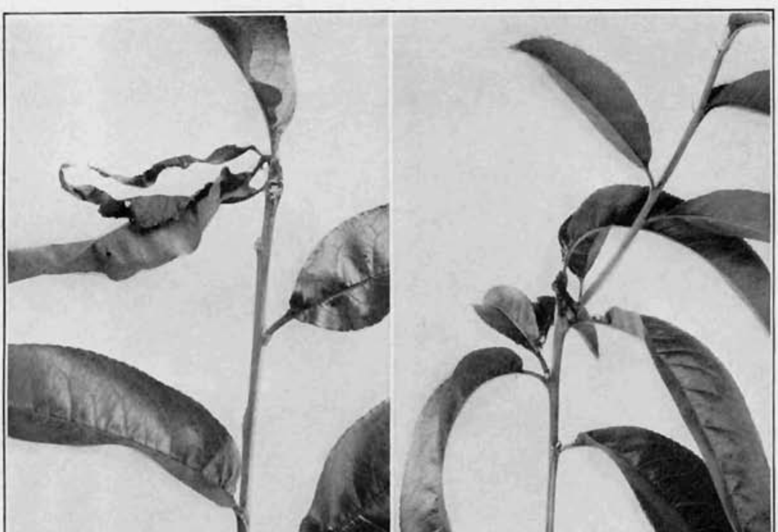
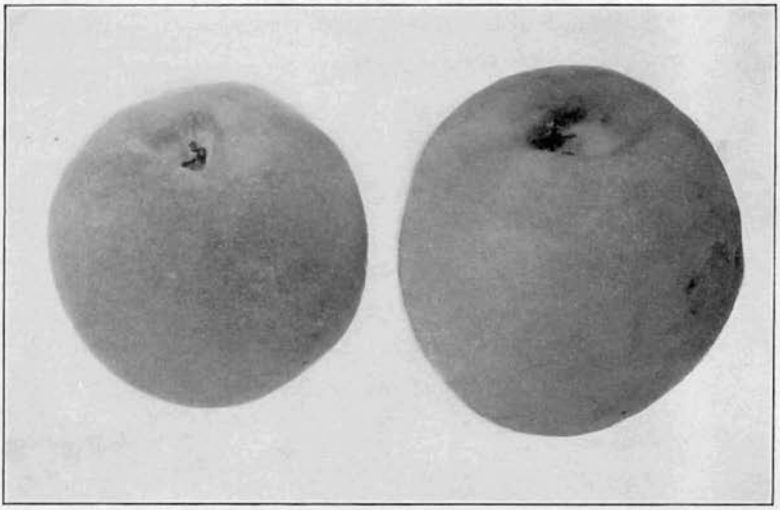


a. Newly infested twig, left; more advanced stage, right.

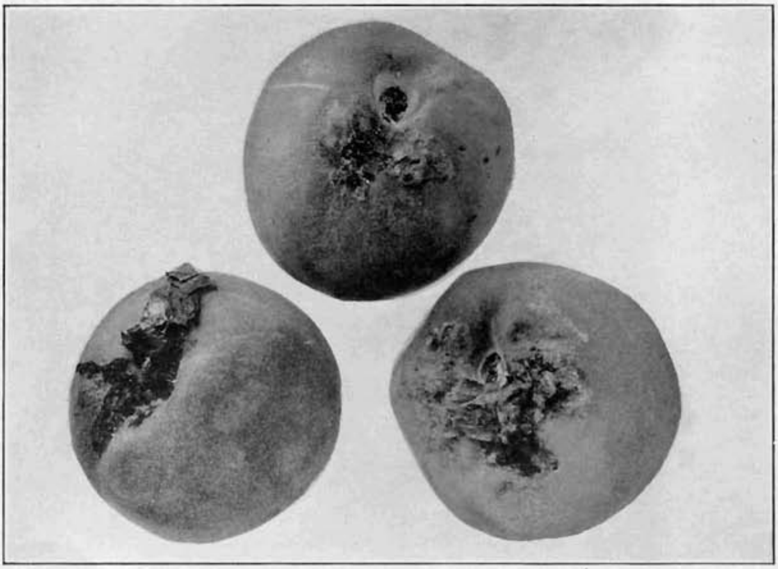


b. Injured twig after the larva has abandoned it, left; similar twig still later showing how laterals are forced out, right.

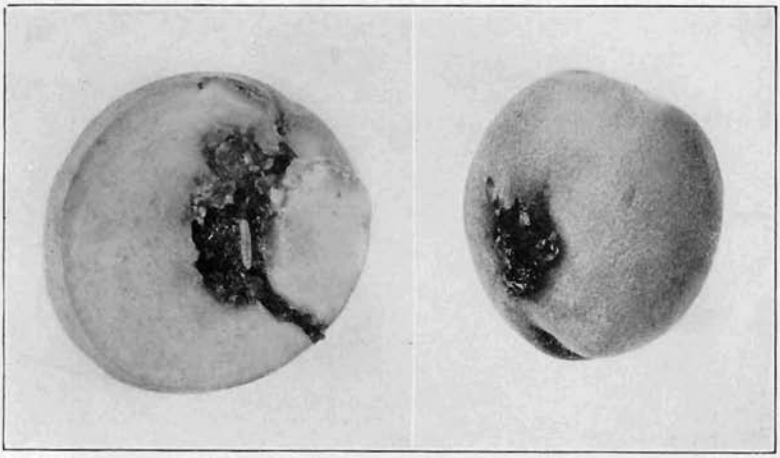
PLATE II



a. Ripe fruit with inconspicuous entrance marks of larvae near stems, late brood.



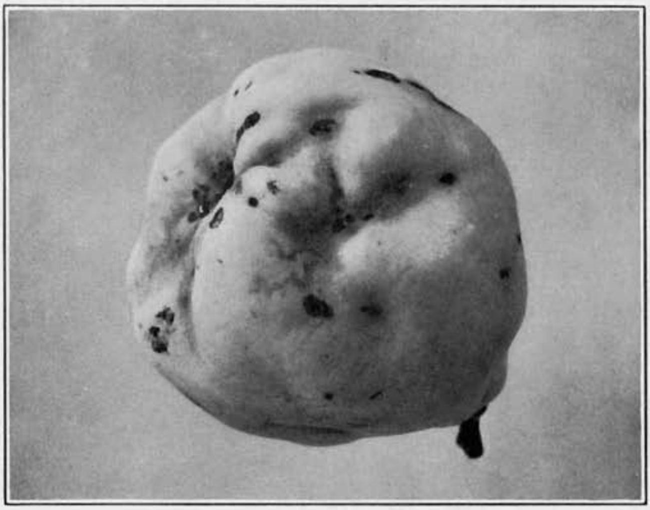
b. Exterior marks of infestation, early brood.



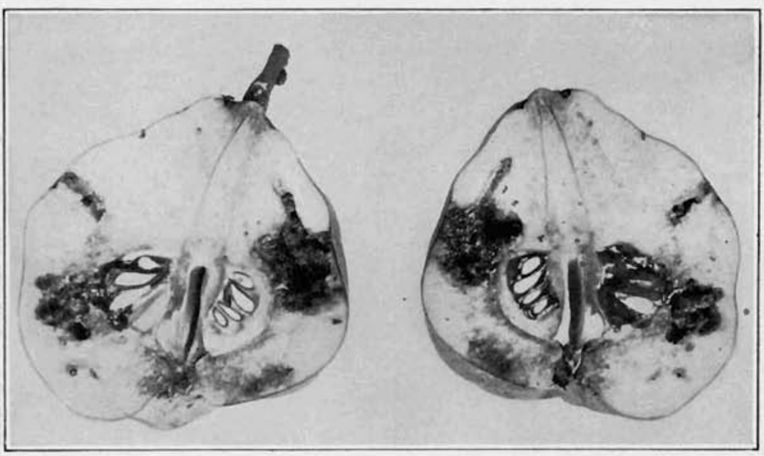
a. Peach with nearly full grown larva, left; exterior marks of infestation, right.

b. Ripe peach containing two larvae.

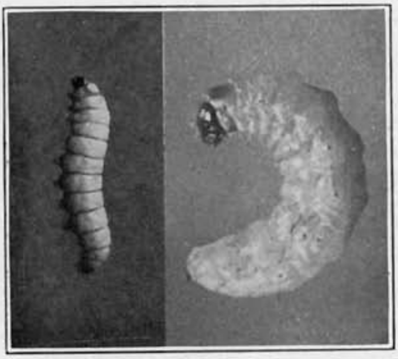
PLATE IV



a. Mature quince infested with Oriental peach moth.



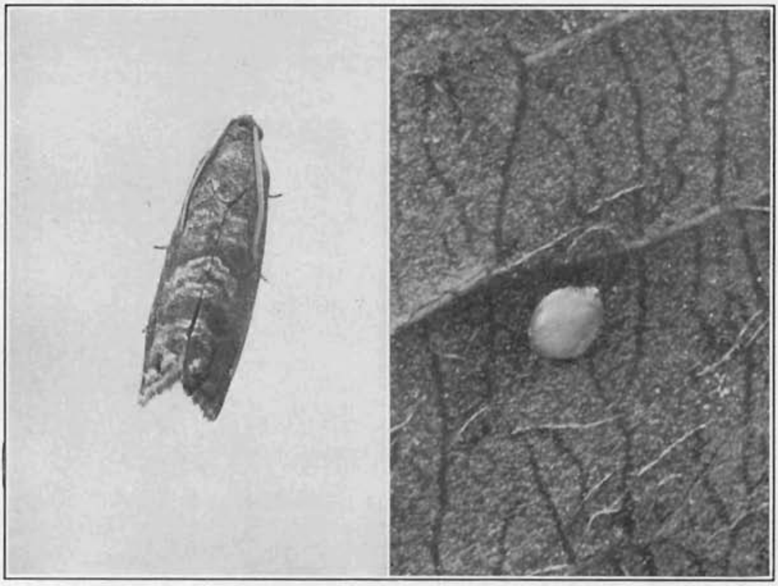
b. Quince cut open to show condition of the interior.



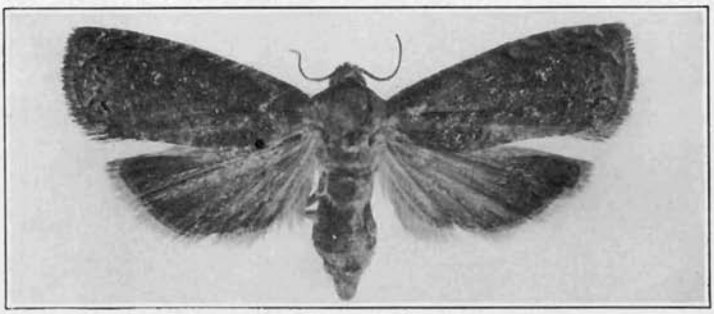
a. Larva of Oriental peach moth and plum curculio compared: left, Oriental peach moth full-grown larva; right, full-grown curculio larva. Both considerably enlarged.

b. Infested peach showing exit hole of larva.

PLATE VI

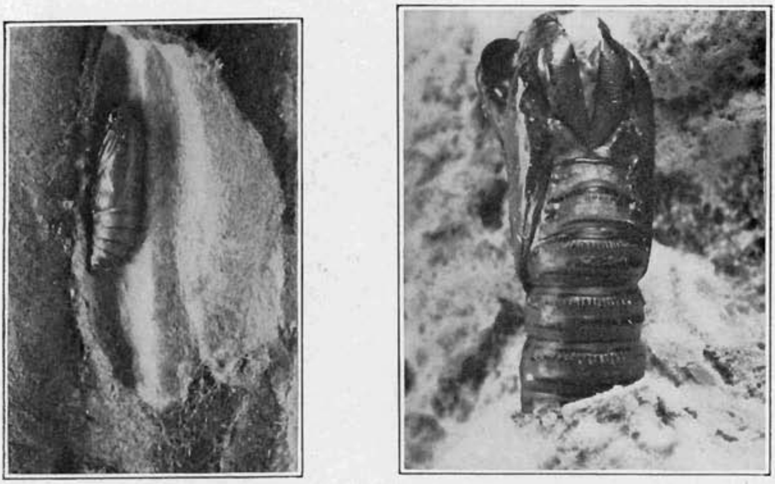


a. Left, adult moth, enlarged six times; right, egg, enlarged eighteen times.

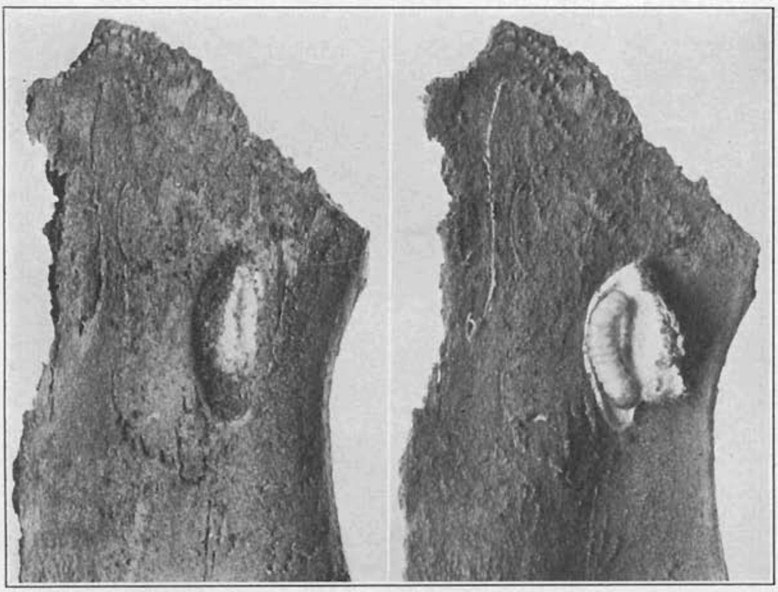


b. Adult female moth enlarged six times.

c. Eggs on surface of peach leaf obtained in insectary cage, enlarged ten times.

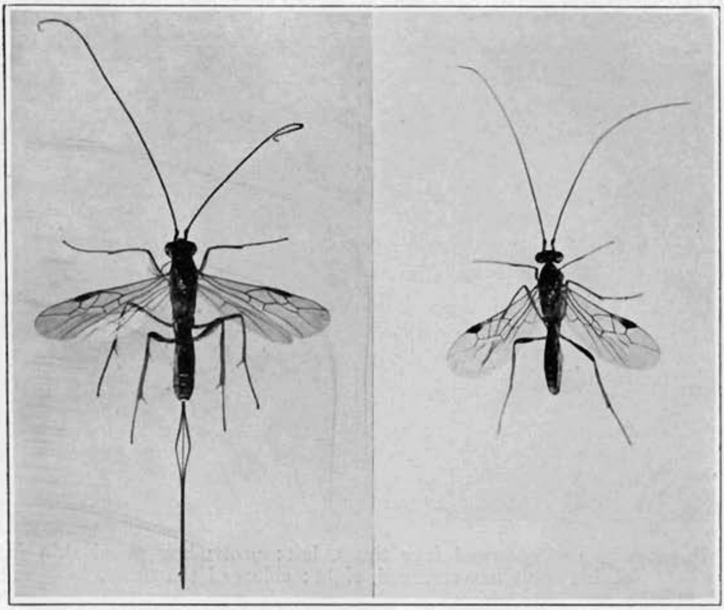


a. Pupa in cocoon enlarged four times, left; protruding pupal skin from which adult has emerged, right; enlarged ten times.

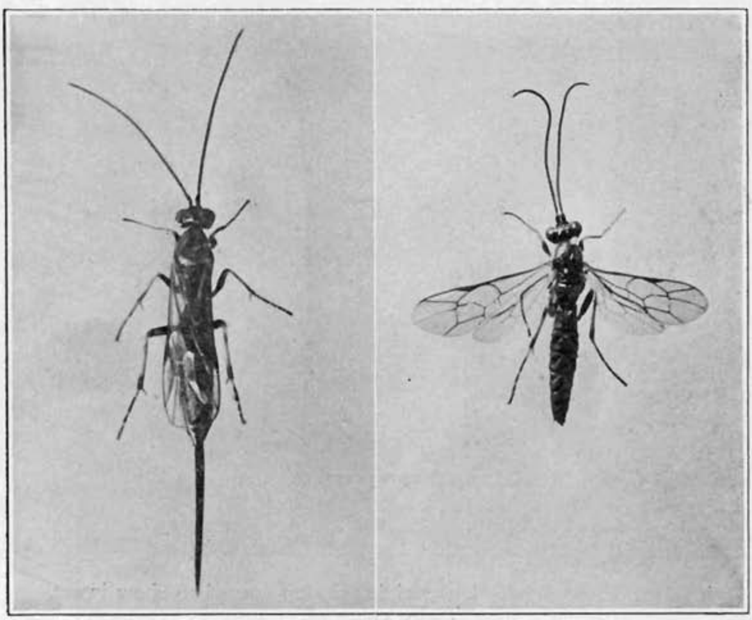


b. Left, cocoon under bark; right, cocoon opened to show insect. Twice enlarged.

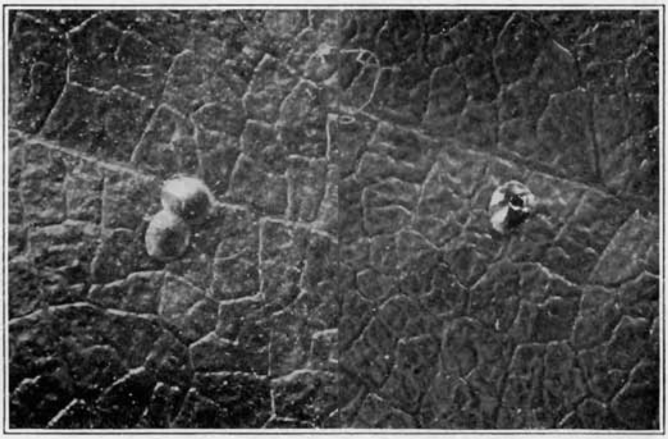
PLATE VIII



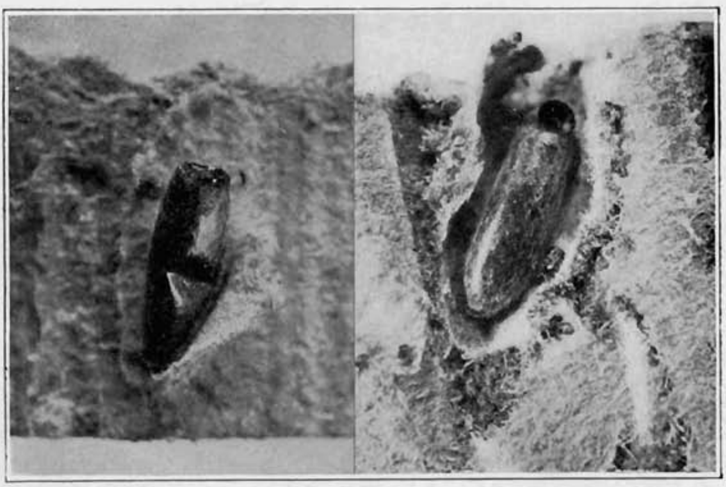
a. *Macrocentrus ancylivora* Rohwer, female, left; male, right. Enlarged four times.



b. *Glypta rufiscutellaris* Cresson, female, left; male, right. Enlarged four times.

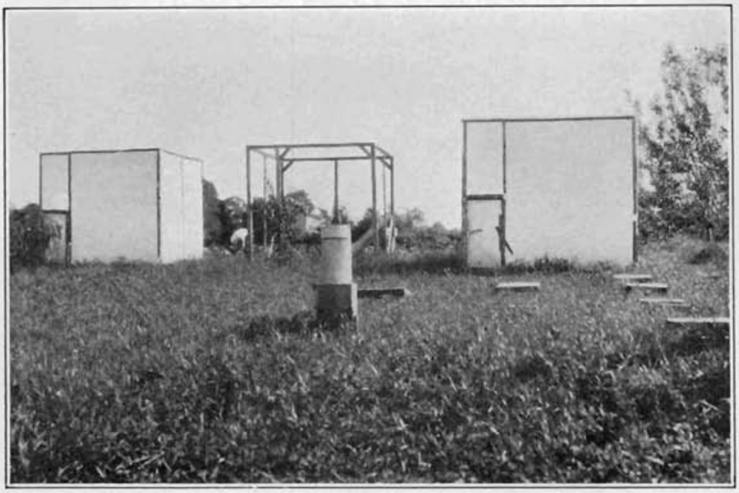


a. Eggs parasitized by Trichogramma, left; egg from which parasite has emerged, right.

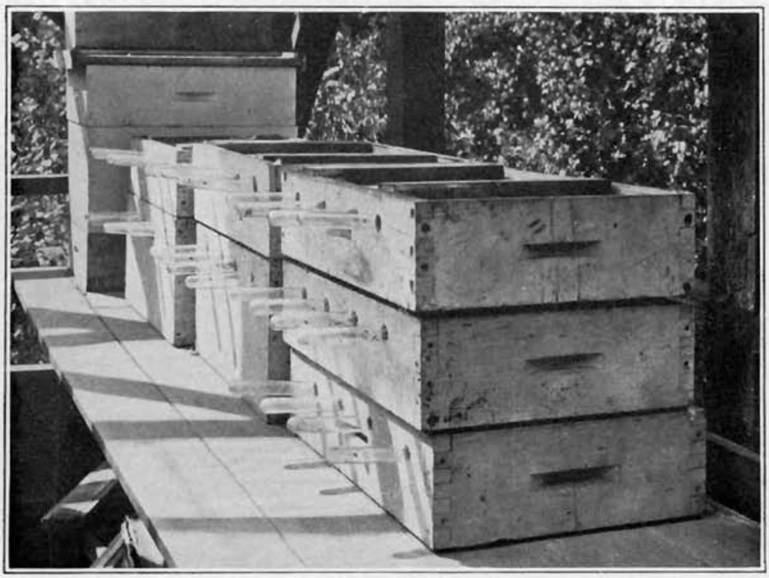


b. Cocoons of *Macrocentrus ancylivora* Rohwer.

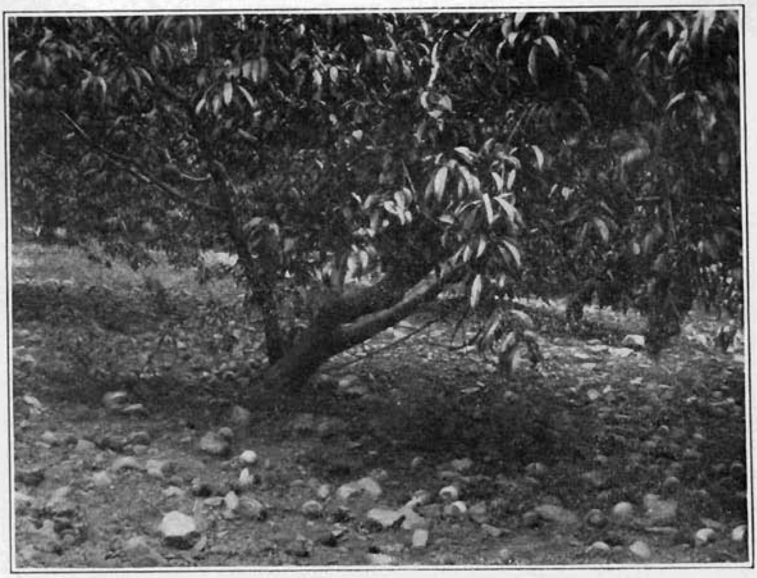
PLATE X



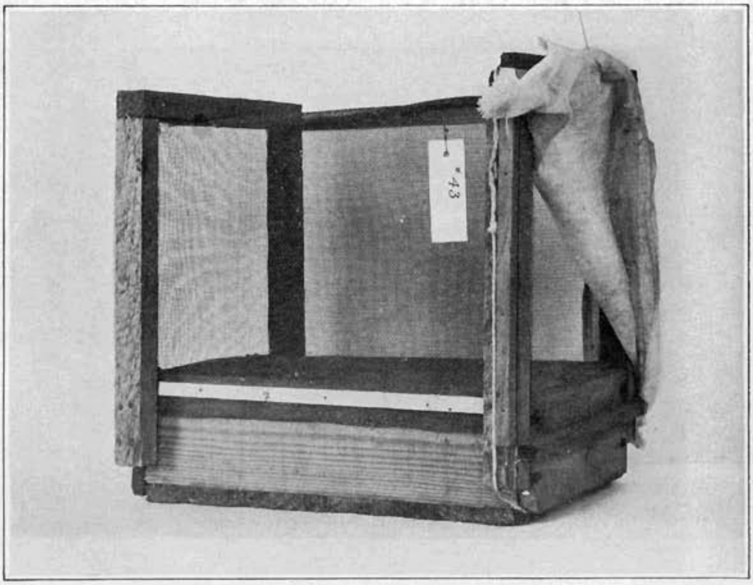
a. Tree cages at Mount Carmel farm used in studying the Oriental peach moth.



b. Trays used for emergence of *Macrocentrus ancylivora* in 1929.



a. Drop fruits in a heavily infested orchard. Many more than this are sometimes seen.




b. Cage used for obtaining eggs of the Oriental peach moth. This cage is so constructed that no smooth surface is presented to the moths for oviposition. Peach shoots are placed within and moist sand in the bottom tray. Constructed by Mr. J. F. Townsend, slightly modified from a cage in use by the Federal Government at Moorestown, N. J.

PLATE XII

a. Outfit used in spraying peach trees, Conyers farm, Greenwich.

b. Dusting outfit used at Conyers farm, Greenwich.