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Oriental Fruit Moth Investigations in Ohio. II

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Wooster, Ohio

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ORIENTAL FRUIT MOTH INVESTIGATIONS IN OHIO. II.

R. B. NEISWANDER[1]

INTRODUCTION

Two former publications (15, 16),[2] which were published in 1928 and 1930, presented information on the biology of the Oriental fruit moth, together with a record of the control experiments with insecticides carried on during the years 1927, 1928, and 1929. Since 1929, some additional work of a biological nature has been done and the investigations with insecticides have gradually been replaced with studies of the insect enemies of this pest. Particular emphasis has been given to the work of introducing and distributing certain of these parasites from the New Jersey peach belt and definite progress apparently has resulted. It is the purpose of the present publication to summarize these findings during the period 1929 to 1935 in order that they may be made available to the fruit growing interests of the State.

It was mentioned in the previous bulletin that infestation records indicated a larger fruit moth population in the State as a whole at the close of the 1929 season than at any time since the introduction of the pest in Ohio. In 1930, due in part to the severe drouth and to the complete failure of the peach crop in central and southern Ohio, the fruit moth populations in those areas were greatly reduced. In northern Ohio, where a partial crop was produced, the infestation continued high. In 1931 a few orchards in northern Ohio showed a decrease in infestation, but the population in that area as a whole probably reached its highest level that year. In central and southern Ohio the population, although fluctuating somewhat, has not been as severe in more recent years as it was in 1928. The status of the insect at the present time will be discussed more fully in another part of this bulletin, but it may be stated briefly at this point that, in general, the damage throughout the State in 1935 was the lowest it has been since the Oriental fruit moth became generally established.

BIOLOGICAL STUDIES

SEASONAL LIFE HISTORY

The seasonal life history of the fruit moth, as it occurs in southern Ohio, was presented in the previous bulletin (16). It was shown that five broods of eggs and larvae developed in 1927; this is the usual condition in southern Ohio, although there are commonly only four in the northern part of the State. The relative seasonal abundance has changed since the former publication appeared. At that time the "third and fourth broods of eggs and larvae were by far the largest, and of approximately equal dimensions". Due largely to the activity of parasites, the third and fourth broods have become smaller, with the result that now the second brood is usually the most abundant. This is shown in Figure 2, which is a graphical presentation of the weekly catch of moths in bait traps during 1930, 1932, and 1934.

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[1]The writer was assisted by Mr. M. A. Vogel during 1930, 1931, and 1932.

[2]Numbers in parentheses refer to the list of literature cited on the final page of this bulletin.

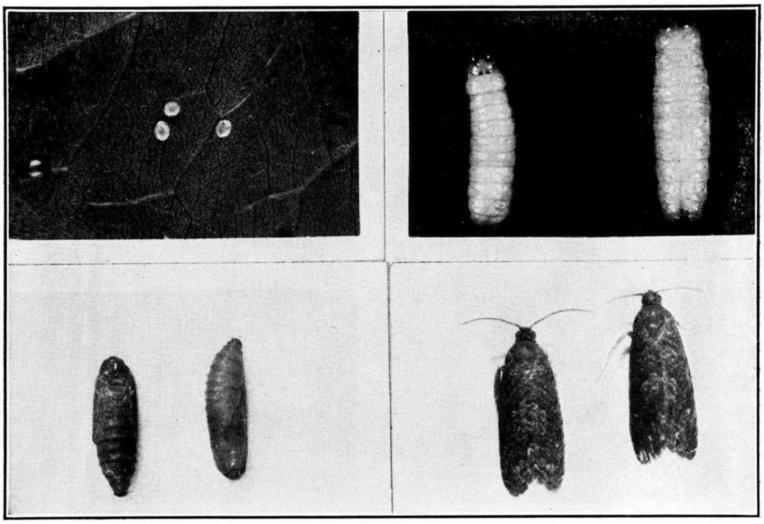

Fig. 1.—The egg, larval, pupal, and adult stages in the life cycle of the Oriental fruit moth. All photographs are much enlarged

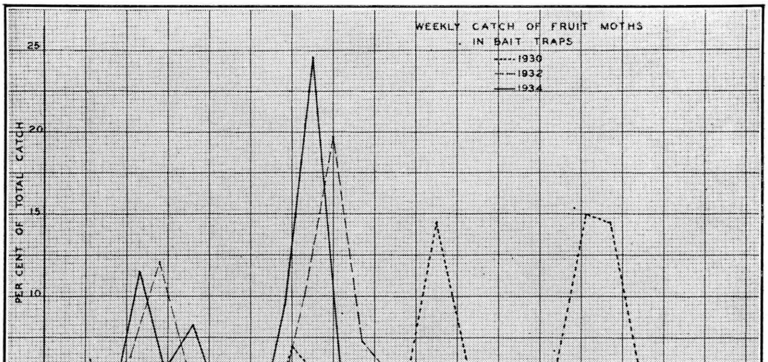

Fig. 2

The occurrence of so many broods each year constitutes one of the factors that make this insect a severe pest. Even though the overwintering population is small, sufficient numbers can be produced before peach harvest to do much damage to fruit. If a calculation is made on the basis that spring brood moths average 20 eggs per female and that moths of the first, second, and third broods oviposit at the rates given by Stearns and Neiswander (16), it is found that a fertilized spring brood female might be responsible for the production of over 140,000 eggs of the fourth brood, provided no mortality occurred in the interim.

Records have been obtained which show that the potential production of the Oriental fruit moth may be higher than these figures indicate. In three breeding cages, containing 10 females each, an average of 129.0 eggs per female was deposited at the Wooster insectary in 1932. Moreover, Steiner and Yetter (17) found by dissecting female moths that an average female contained as many as 200 eggs.

EARLY SEASONAL DEVELOPMENT

The time of emergence of spring brood moths varies greatly in Ohio from year to year. It also varies for different parts of the State during the same year.

A record of the emergence time of the spring brood in different parts of the State has been obtained for 7 successive years. This was done by transporting each autumn, to various parts of the State, hibernating larvae which had been reared in the insectary and had spun cocoons in narrow strips of corrugated paper. In 1928, each larva in its respective corrugation was placed in a vial, but in the 6 following years the corrugations were attached to a post and enclosed in a screen cage (16). Each year from 200 to 300 larvae were taken to each locality where they were exposed to outdoor weather conditions until emergence was complete. Daily observations were made and the number of moths which appeared was recorded.

The records indicated might be held to be of somewhat questionable value because the larvae were reared under artificial conditions and because some lots were transported for considerable distances. However, the adult emergence records each year correspond to the development of the peach trees in the locality in which each cage was located. Likewise, the first appearance of injury to twigs in the field synchronized closely with the time the emergence of the moth indicated it should be found.

TABLE 1.—First Emergence Dates, 1928 to 1934

Locality	1928	1929	1930	1931	1932	1933	1934	Mean
Ironton	4/30	4/ 7	4/ 8	4/19	4/ 3	4/21	4/ 2	4/13
Cincinnati	5/ 6	4/ 7	4/13	4/21	....	....	....	4/19
Chillicothe	5/ 6	4/ 7	....	4/22	....	....	....	4/22
Columbus	5/ 5	4/ 8	....	4/29	4/10	5/ 2	5/ 2	4/24
Wooster	5/14	4/24	5/ 1	5/ 3	5/ 3	5/12	5/ 7	5/ 5
New Waterford	5/11	4/27	5/ 3	5/ 9	....	....	....	5/ 5
Danbury	5/23	5/ 9	5/ 7	5/13	....	....	5/18	5/14

At Ironton, as shown in Table 1, the first moths emerged on April 2 in 1934 and on April 30 in 1928, a difference of 28 days. At Wooster, first emergence occurred on April 24 in 1929 and on May 14 in 1928, a difference of 20 days.

If the variation between different localities in the State for a given year is considered, it will be seen that first emergence in 1929 varied from April 7 in southern Ohio to May 9 at Danbury, in northern Ohio, a difference of 32 days. In 1934 in the same localities it varied from April 2 to May 18, and the mean of all records obtained shows first emergence at Danbury to be 31 days later than at Ironton.

A graph in the previous bulletin indicates the dates of appearance of the spring brood at several points in Ohio. Additional data have been accumulated on this point during recent years and are recorded in Table 2.

TABLE 2.—Relationship of First Emergence and Latitude

Locality	Miles north of Ironton	Days of delay in emergence
Cincinnati	48	6
Chillicothe	57	9
Columbus	105	11
Wooster	159	22
New Waterford	162	22
Danbury	208	31

When the data presented in Table 2 are analyzed, it is found that a distance of approximately 7½ miles northward results in an average delay of 1 day in the appearance of the moths. The correlation coefficient representing the relationship between "miles north of Ironton" and "days of delay in emergence" is 0.97.

In order to compare the early seasonal development of the insect with its host, the date when Elberta peaches were in full bloom was recorded for several areas in which emergence cages were placed. These data are shown in Table 3.

TABLE 3.—Approximate Dates When Elberta Peaches Were in Full Bloom

Locality	1929	1930	1931	1932	1933	Mean
Ironton	4/ 4	4/ 8	4/17	....	....	4/10
Cincinnati	4/ 5	4/14	4/17	....	....	4/12
Chillicothe	4/ 6	....	4/20	....	....	4/13
Columbus	4/10	....	4/28	....	....	4/19
Wooster	4/12	4/21	4/30	4/24	4/26	4/23
New Waterford	4/18	4/24	5/ 5	....	....	4/26
Danbury	4/25	5/ 1	5/ 7	5/ 7	....	5/ 3

It is evident from a comparison of Tables 1 and 3 that a close correlation exists between the development of the peach tree and fruit moth emergence. In general, first emergence appears a few days after full bloom of Elberta peaches in each locality. The relationship of fruit moth emergence to full bloom of Elberta is shown graphically for seven localities in Ohio in Figure 3.

DEVELOPMENT OF SUMMER BROODS

The time when the moths of the various summer broods appear is shown distinctly by records of the relative numbers of adults caught in bait traps operated continuously throughout the season. Traps have been employed in Ohio chiefly to determine the relative activity of the moths in the orchard. No definite attempt has been made to determine their efficiency as a control measure, although there is a possibility that they might prove to be of considerable value in this respect. The records obtained during three seasons are shown graphically in Figure 2. The time when the peak of the catch of spring brood moths appears varies greatly from year to year, but the later broods correspond more closely, the variation decreasing as the season advances.

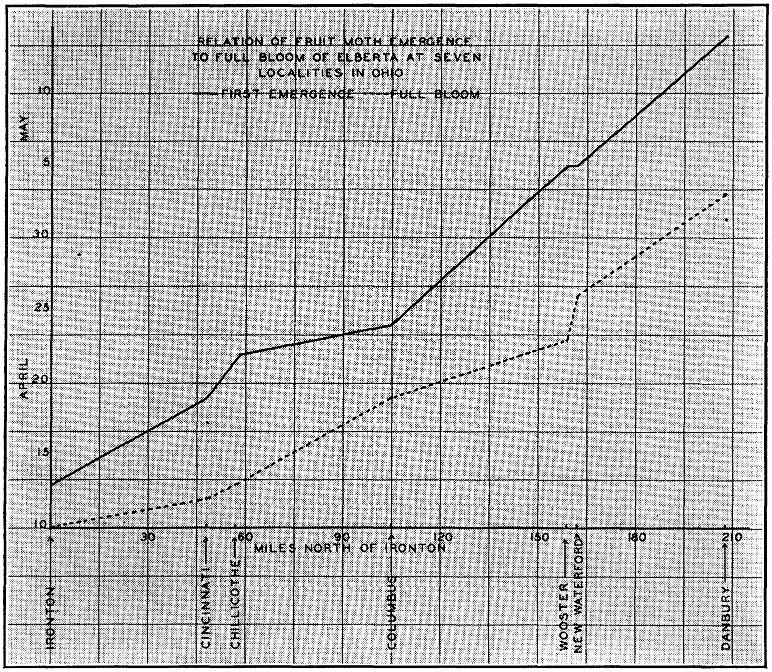

Fig. 3

It will be seen in a study of Figure 2 that moths were caught each week from early May until October during each of the 3 years. In all cases the various broods overlapped to a certain extent and the overlapping increased as the season advanced. A comparison of the development of the summer broods in quinces with that in peaches has been discussed in a previous publication (6).

LOCATION OF COCOONS

WINTER COCOONS IN ORCHARDS

The fact that fruit moth larvae hibernate in weeds, trash, and mummied fruits on the ground under peach trees, as well as in roughened bark, etc., on the trees, has been known for a number of years. Stearns (14) reported for New Jersey conditions that thorough cultivation would kill those on the ground. Since that time, spring cultivation frequently has been recommended to growers.

In order to get some information on the relative numbers of fruit moth larvae that would be killed by this operation in Ohio, a number of trees were examined before emergence of the spring brood began in each of the seasons of 1930, 1931, and 1932.

In conducting this study, all limbs and twigs of each tree were examined and the loose scales of bark were picked off. The ground within 6 inches of the trunk and to a depth of approximately 1 inch was sifted through a 14-mesh screen. All trash that would not go through the screen was carefully dissected. In addition to the 6-inch area around the trunk, a quarter section of the surface beneath the spread of the branches was treated in the same manner. In order to determine the approximate total number of larvae on the ground beneath the tree, the number found in this quarter section was multiplied by 4 and added to the number found within the 6-inch area surrounding the tree. The data are summarized in Table 4.

TABLE 4.—Fruit Moth Larvae Hibernating on and under Peach Trees

Peach variety	Larvae on ground		Larvae on tree		Total	Number of trees
	Number	Pct. mortality	Number	Pct. mortality		
Krummel	104	57.7	149	77.2	253	1
Salway	79	11.4	132	25.8	211	6
Heath	60	6.7	10	10.0	70	1
Smock	25	0.0	50	6.0	75	2
Lemon Free	40	35.0	39	69.2	79	3
Carmen	9	11.1	1	100.0	10	1
Total or average	317	27.8	381	47.5	698	14

The tree of the Krummel's October variety, which yielded a total of 253 larvae, was quite old and the bark was very rough, thus providing favorable quarters for the fruit moth larvae. A considerable number of mummied peaches remained under the tree, and this may have been a further contributing factor. Thirteen of the 14 trees studied were on ground that had been cultivated during the previous season. It will be noted that approximately 50 larvae per tree were found, of which 55 per cent was located on the tree. It will be observed also that the mortality on the tree was greater than that on the ground.

In the case of eight of the 14 trees studied, a record was taken of the numbers of larvae so located that they might be killed by an application of paradichlorobenzene. It was found that 21.6 per cent was in such a position.

Four quince trees located in a heavy sod were also examined for hibernating larvae and yielded a total of 302. The sod was not disturbed, but a study of the clumps of grass, plant stems, and refuse on the ground yielded no larvae.

SUMMER COCOONS IN ORCHARDS

Twelve peach trees were examined during the summer time in the same manner as were those in the spring in an effort to determine the percentage of the larvae of the summer broods that form their cocoons on the ground. The task of examining all of the twigs of a peach tree in foliage proved difficult and it is very probable that all of the summer cocoons were not found. Although the record is not absolutely accurate, it establishes the fact that some of the summer cocoons are formed on the ground. A total of 192 larvae was found in cocoons, of which 39.6 per cent was on the ground.

It was thought probable that more nearly accurate information concerning the location of summer cocoons could be obtained by determining the place from which moths emerge. For this purpose four trees were inclosed in cheesecloth cages in 1931 and one in 1932. At the time when most of the larvae were in cocoons, a horizontal cheesecloth partition was placed in each cage in such a position that the moths emerging from the ground were confined in one compartment and those emerging from the tree in the other. The record obtained showed that in the five cages a total of 93 moths emerged from the trees and 14 from the ground.

COCOONS IN STORAGE SHEDS

Packing houses or sheds in which equipment used in harvesting peaches is stored frequently provide hibernating quarters for many fruit moth larvae. Four such sheds have been examined in Ohio and in each case considerable numbers of living fruit moth larvae were found. Although larvae were observed in various places in these sheds, the greatest number were in used baskets. One hundred baskets were examined in the four sheds and 372 fruit moth larvae were found. The maximum number found in one basket was 37. The mortality varied from 3 to 9 per cent, which was much less in each case than that occurring in orchards in the same vicinity. Since the baskets were stored for further use, it was not permissible to tear them apart; hence, it is probable that all of the larvae were not discovered.

The degree of worminess of fruit handled and the length of time it is permitted to stand on the premises will, of course, influence the number of larvae hibernating in storage sheds. In the case of a shed where large quantities of wormy peaches or quinces are permitted to stand for a few days or where many used baskets are stored, it would be advisable, if the packing house is well constructed, to close it the following spring during the period of moth emergence in order to confine the insects. If too many openings preclude this plan, it would be well to dip the used baskets in a vat of boiling water, since they harbor the majority of the insects.

HOSTS ATTACKED

The fact that larvae feed in both twigs and fruits of a number of plants enables the pest to survive seasons that otherwise would greatly reduce the population. In Ohio orchards, larvae have been found feeding in the fruits of peach, apple, quince, pear, and plum and have been reared in the insectary in the same types of fruits. They have been found feeding in the twigs of peach, apple, sweet cherry, and rose. The fact that they were feeding in rose stems was probably accidental, since the bush in which the larvae were found was only 2 or 3 feet from the tips of branches of a young peach tree that was heavily infested. It seems unlikely that the eggs were deposited on rose foliage. In rare instances only have larvae been found in apple twigs. Young larvae have been induced to feed on geraniums in the insectary but none have been reared to maturity on this host.

Larvae have been reported by other workers (1) as feeding on the fruit of apricot, nectarine, cherry, persimmon, and sand pear and on the twigs of apricot, nectarine, pear, plum, flowering cherry, and both fruiting and flowering quince.

SEASONAL VARIATIONS IN THE MORTALITY OF FRUIT-FEEDING LARVAE

In the process of conducting laboratory spraying experiments, considerable variation in percentage survival of larvae applied to untreated as well as treated peaches was very evident. It was noted that a greater percentage of the larvae survived in tests conducted during the latter part of the summer than in those conducted during midsummer. Since this seemed to correspond to the growth stages of the peach (2), an effort was made in 1932 to get more information on this point.

An experiment was conducted in which measurements of the relative size and hardness of fruits were made each week. The length, suture, and cheek dimensions of 50 peaches were measured by means of a vernier. The rate of growth was determined by obtaining the average of the three dimensions and subtracting the average diameter for each week from the average for the following week. The relative hardness of the same peaches was determined by recording the number of pounds pressure necessary to drive a truncate pin ⅛ inch in diameter ¼ inch into the flesh of the peach. The 50 peaches were always taken from four trees and different trees were selected each week.

During several seasons fruit moth eggs in the black spot stage were applied every few days to untreated peaches taken directly from the orchard. Peaches with approximately 6-inch stems were selected and, after each peach was placed with its stem in a separate bottle of water, five eggs on a small piece of cellophane were attached to each fruit by means of shellac. The peaches were then transferred to a small room where a high degree of humidity was maintained to prevent them from drying too rapidly. The bottles were placed in racks in which each was surrounded by a narrow barrier of tanglefoot in order to account for any larvae that might leave the fruit. The peaches were left in this room for several days to permit the eggs to hatch and the larvae to enter the fruit and become large enough to be found readily. The peaches were then dissected and the percentage of larval survival was determined.

The data obtained in this study of larval survival, rate of peach growth, and hardness of the fruit are shown in Table 5.

TABLE 5.—Larval Survival, Hardness of Peaches, and Rate of Peach Growth

Period	Number of larvae applied	Number of larvae recovered	Per cent survival	Hardness of peach	Rate of growth
				Lb.	*In.*
6/ 6–6/13	50	16	32.0	8.67	0.316
6/14–6/20	130	31	23.8	10.05	0.211
6/21–6/27	151	52	34.4	11.03	0.156
6/28–7/ 4	139	41	29.5	11.66	0.018
7/ 5–7/11	108	27	25.0	12.44	0.020
7/12–7/18	207	51	24.6	10.69	0.031
7/19–7/25	276	85	30.8	11.41	0.043
7/26–8/ 1	532	165	31.0	10.25	0.059
8/ 2–8/ 8	516	199	38.6	9.83	0.044
8/ 9–8/15	358	157	43.9	8.07	0.079
8/16–8/22	353	144	40.8	7.33	0.141
8/25–8/30	400	187	46.8	5.70	0.253

The variation in percentage of larval survival corresponds to that obtained by Dustan (4). Survival is relatively high during the early part of the season but decreases during the fore part of July. During August, it again increases significantly. It is evident also that, as the relative hardness of the peaches increases, the percentage of survival decreases. The correlation coefficient was found to be —0.80.

The data also indicate a relationship between rate of growth and percentage of survival. The percentage of survival tends to decrease as the growth rate decreases. It seems probable, however, that this relationship is indirect and that the rate of growth influences the percentage survival chiefly through the resulting degree of hardness of the flesh of the fruits. The correlation coefficient representing this relationship was found to be 0.32. These relationships are shown graphically in Figure 4.

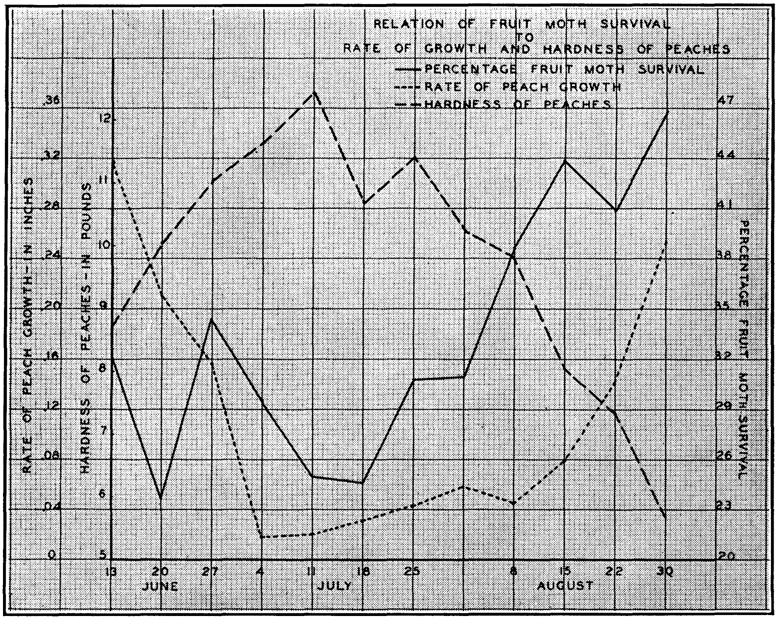

Fig. 4

These studies seem to indicate that the welfare of the larval brood which is present when the peach fruits are in a partly grown, hard stage has an important bearing on the degree to which the ripe fruit is damaged. If the season is such that succulent twig growth is available during this critical period and the larvae are not forced to subsist in the hard, green peaches, damage to the ripening fruit is more likely to be severe.

VARIATIONS IN FRUIT MOTH DISTRIBUTION

A number of factors which influence the infestation appearing in an orchard at picking time have already been discussed. Among those mentioned are the number of broods developing during the season, climatic conditions which influence winter and summer mortality, varieties of fruits grown, and cultural practices.

Variations in infestations appear, however, that as yet have not been accounted for. Differences between parts of the same tree, between trees, and between parts of the orchard are constantly appearing. The differences between parts of the orchard are frequently very wide and are often evident throughout the season. The Nussdorfer orchard at Avon Lake, which was employed in experimental spraying work for four successive seasons beginning in 1930, offers a striking example.

From July 29 to August 1, 1930, the average number of injured twigs per tree in the four south rows was found to be, respectively, from south to north, 48, 35, 23, and 21. The fruit infestation taken early in September in the same four rows was 18.1, 10.5, 9.3, and 6.9 per cent, respectively. The plots which made up the south range, in all cases but one, showed a higher infestation in both the twig count and the fruit count than the plots in other parts of the orchard that received similar treatments. The correlation coefficient obtained by comparing the twig injury and fruit injury in the 54 plots was 0.622 with odds of over 10,000 to 1 that the correlation was significant. This seems especially noteworthy in view of the fact that six of the 54 plots were sprayed three times, 21 were sprayed twice, and 24 were not sprayed between the dates when the infestation counts were made. The natural variation was such that, even though the sprays reduced the fruit injury, in one case as much as 80 per cent, the relationship between the twig- and fruit-feeding populations was still evident.

In 1931 approximately the same conditions existed that prevailed in 1930. The south side of the orchard was again found to be the most heavily infested throughout the season. The total number of injured twigs on each tree was counted twice, the first count having been made on June 29 and 30 and the second from July 29 to August 4. In the first twig count the six rows making up the south range of plots averaged, respectively, from south to north 17.1, 12.5, 9.2, 4.7, 3.9, and 4.9 injured twigs per tree. The same six rows in the second twig count averaged 101.8, 101.2, 85.6, 72.6, 76.7, and 82.0, respectively. No fruits were examined in the two outside rows on the south side, but the fruit examined from the four remaining rows averaged, respectively, 35.6, 21.0, 15.8, and 19.8 per cent wormy. A correlation coefficient of 0.55 was obtained between the first twig count made during the last 2 days of June and the fruit count made during the middle of September.

In 1932, although the differences were not quite as outstanding as during the two previous seasons, the south side of the orchard was still the most heavily infested. A correlation coefficient of 0.694 resulted between the first twig count and the fruit count. No satisfactory infestation counts were made in the south side of the orchard in 1933.

The outstanding fact resulting from the 3 years' infestation records in this orchard is the consistently heavier damage to the south side; this diminished gradually in a northerly direction and remained consistent throughout the season. Similar conditions have been observed in a less detailed manner in other orchards in that border rows quite commonly have been found to be the more heavily infested. Undoubtedly, ecological influences are the controlling factors, but the exact nature of these has not been determined definitely.

In the case of the Nussdorfer orchard it was thought that a study of the soil types represented might solve the problem, but, when these were mapped by Dr. G. W. Conrey of the Department of Agronomy of the Ohio Agricultural Experiment Station, no very apparent relationship was evident between soil type and fruit moth infestation. One suggestion which presented itself is that after the peach crop was harvested the fruit moths migrated to the more favorable hibernating quarters in the adjoining apple orchard to the south. However, no appreciable fruit moth infestation was noted in the apple orchard at any time. The theory advanced by several workers in attempting to account for peculiarities in fruit moth distribution is that prevailing winds may cause definite concentrations of adults in certain areas of the orchard. In the Nussdorfer orchard, high winds are not uncommon but wind direction shifts too often to account satisfactorily for the conditions described.

CONTROL STUDIES WITH INSECTICIDES

EXPERIMENTS WITH ELBERTA PEACHES

It was concluded in the publication of 1930 (16) that: "The results of extensive laboratory tests and both cooperative and experimental orchard spraying, emphasize the belief that a probable summer control for this insect will result through a succession of early season sprays which will include hydrated lime or some like material acting as a physical or mechanical hindrance to oviposition, hatching, and larval activity." Hydrated lime was used extensively in later experiments and proved effective when a heavy coating was maintained, but such a coating on fruit at picking time is undesirable. In order to permit rains to wash the lime from the fruit, it was found necessary to discontinue spraying nearly 8 weeks before harvest. This allowed the unhampered development of two late season broods. Thus, the ripening fruit was unprotected during the most critical period of the year.

It was mentioned also in the publication referred to that summer oils when used in laboratory tests seemed to be quite effective in destroying both eggs and larvae of the fruit moth. The summer oils were used extensively during succeeding years, but before taking them into commercial orchards they were tested thoroughly in small scale experiments on young Elberta peach trees near the insectary at Wooster. Four commercial summer oils were used in these tests, three at the rate of 2 gallons and the fourth at 1½ gallons in 100 gallons of spray. Each oil was used on at least nine trees and applications were made at approximately weekly intervals with a standard Friend Sprayer at a pressure of 250 pounds, beginning April 30.

Little spray injury was noted on any of these oil plots until after the ninth application when some slight defoliation was noted and two of the oil-sprayed plots seemed to show slightly less growth than the untreated trees. Early in August a slight roughening of the bark began to appear which became more severe as the season advanced. In September this was evident with greater or less intensity on all trees in the four oil plots. It is difficult to explain this condition, but it seems probable that it was due to an increased growth of cork tissue around the lenticels. The fourteenth and last application was made on August 7. At that time one plot showed severe defoliation and consequently was not given this treatment. Figure 5, taken on September 15, shows the condition of the bark on the trees of the four oil plots and of an unsprayed plot.

An examination of these trees in the spring of 1931 showed that the oils had influenced the set of fruit buds. In all cases the set of fruit buds was less than half that of the untreated trees.

In view of the fact that under this severe test on young trees no injury was noted until after the ninth application, it seemed that no appreciable injury should result from four or five applications on bearing trees. Consequently, experiments were executed in which summer oils were used during four consecutive seasons in an orchard of approximately 700 Elberta trees at Avon Lake. Treatments were applied either in triplicate or quadruplicate and from seven to 18 formulae were employed each year. Summer oil was included in nearly every test except the check, and no appreciable spray injury resulted from the use of oil in any case.

In 1930, in order to determine the time of the season when sprays would be most effective, schedules were so arranged that a series of oil sprays applied at 10-day intervals would start at varying times during the season. Verdol was used alone in these experiments, although the combination of hydrated lime and lead arsenate was applied in the regular shuck-fall and 2-week sprays.

The results of these tests indicated that the oils were most effective when applied during the period just prior to ripening. The schedule that gave best results consisted of four oil sprays (in addition to the shuck-fall and 2-week sprays) applied at 10-day intervals beginning July 28 and showed a reduction in visible fruit injury of 80 per cent when compared with the check which received only the two regular sprays.

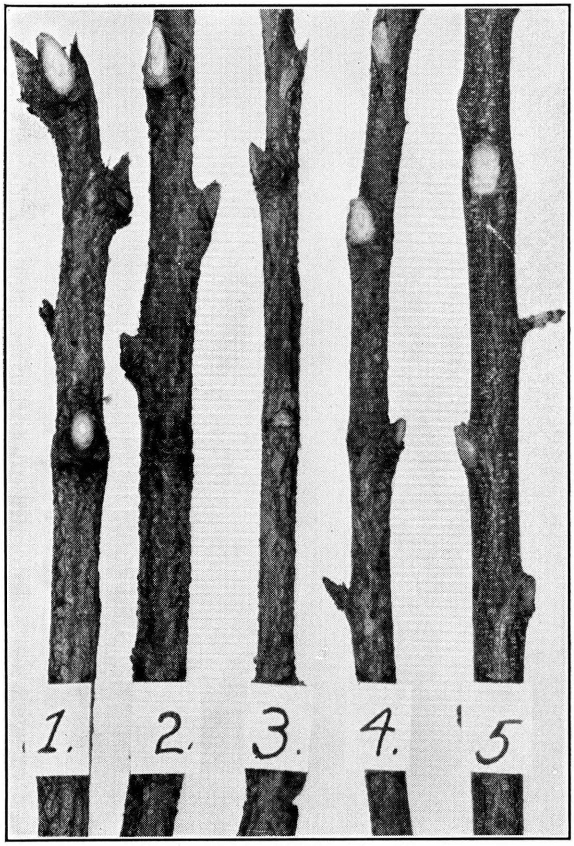

Fig. 5.—Twigs from trees showing the effect of consecutive weekly applications of summer oil sprays. Twigs 1, 2, and 3 each received 14 and Twig 4 received 13 applications. Different brands of oil were used in each case. Twig 5 is from an unsprayed tree. Note roughened bark on oil-sprayed twigs.

The schedules that gave best results were repeated in 1931 and an attempt was made to improve on them by making five applications at weekly intervals, instead of four at 10-day intervals, during the latter part of the season. Five applications gave slightly better results than four during the same period but the differences were not sufficient to be significant. The infestation was higher than in 1930 and the reduction obtained was somewhat lower. Records of total injury were taken in 1931 and in the succeeding years; whereas only visible injury was considered in 1930.

Extensive laboratory spraying experiments conducted during 1930 and 1931 indicated that the summer oils offered the greatest promise of any commercial insecticide available but that their efficiency could be increased if combined with other materials. Consequently, in 1932 an attempt was made to improve the spraying schedules employed previously by the addition of other materials to the oils. The results showed a combination of oil and nicotine to be better than oil alone, but the performance of oil alone was not as good as that during the previous seasons. The combination gave approximately the same reduction in fruit injury that the oil alone gave in 1931.

In 1933, sprays were applied six times at weekly intervals beginning July 21. The materials that gave best results consisted of combinations of oil with nicotine and of oil with rotenone, both of which reduced the fruit injury 36 per cent.

In all cases where four or five applications of summer oil were made during the latter part of the season the peaches developed more red color and were delayed somewhat in ripening. This permitted them to sell on a more favorable market. A significant point in the results obtained in both 1932 and 1933 was the fact that a large percentage of the injury recorded on the fruit at picking time was visible injury, much of which was present when the first fruit moth spray was applied. Over 80 per cent of the injury in the plots that showed best results in 1933 was of the visible type.

The gradual but pronounced increase in parasite activity during 1930 and succeeding years has resulted in a very pronounced reduction of the third brood population. Consequently, the second brood has become the largest brood of the year and during 1932 and 1933 apparently was responsible for a large percentage of fruit injury appearing in Elberta peaches at harvest. This shifting of the peak of fruit moth population is evident in Figure 2. It seems probable, therefore, that sprays would have been more effective in 1933 if the oil applications had been started 3 weeks earlier.

Dusting experiments were conducted during 1930 and 1931 in which various dust combinations were impregnated with oil and applied with a power duster, but no appreciably significant reduction in fruit moth injury was obtained. The results demonstrated, however, that greater safety attended the application of lead arsenate in dust form than in liquid form to peach foliage. In one experiment, a dust that was 15 per cent lead arsenate was used without foliage injury.

EXPERIMENTS WITH PEACHES RIPENING LATER THAN ELBERTA

Experiments with Lemon Free, Smock, and Salway peaches were conducted during 1931 and 1932. Substantial reductions in fruit injury were obtained in each of these varieties with summer oil and with oil and nicotine, when applied four or five times at from 7- to 10-day intervals during the period just prior to harvest. The best results were obtained with summer oil at 1 per cent and nicotine at the rate of 1 part to 1000 parts of water when the last application was made 10 days before the first picking. In no case, however, was the fruit injury reduced by more than 60 per cent.

EXPERIMENTS WITH QUINCES

Spraying experiments for the control of the fruit moth were conducted in a block of approximately 60 quince trees in Ottawa County during five consecutive seasons. In 1931 the block was divided into two equal plots both of which received five sprays at intervals of about 15 days, beginning July 6. One plot received only hydrated lime. The other received 2 gallons of summer oil and 2 pounds of lead arsenate to 100 gallons of water in the first two sprays and 2 per cent summer oil alone in the three later sprays. The quinces picked from the lime-sprayed block were almost 100 per cent wormy (Fig. 6); whereas those from the oil-sprayed block were 60 per cent worm free (Fig. 7). The lime-sprayed quinces averaged 4.79 exit holes per quince; whereas the oil-sprayed quinces averaged only 0.18. This is a reduction in population of 96 per cent in favor of the oil sprays.

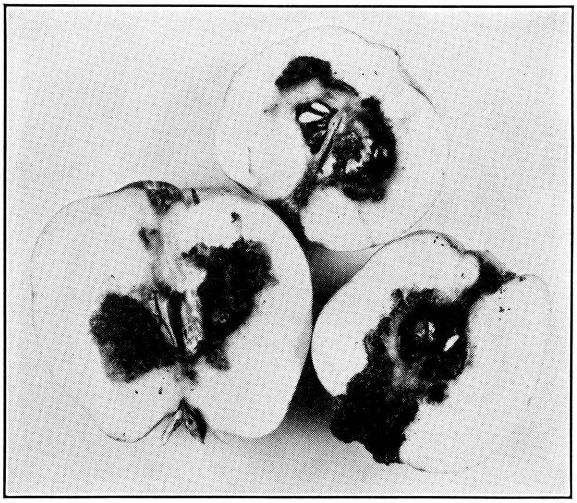

Fig. 6.—Spraying with hydrated lime in 1931 failed to protect quinces

In 1932, the oil-lead spraying schedule described above was repeated and resulted in 16 per cent clean fruit. A combination of oil and nicotine applied during the same period produced quinces that were 20.5 per cent free from damage.

In 1933 the entire block was sprayed five times with a combination of cryolite and oil. The oil, however, was too dilute to have much insecticidal value except as a sticker for the poison. No appreciable reduction in fruit moth injury was obtained.

In 1934 five spraying schedules were employed and each was replicated three times. A combination of oil and nicotine again effected the greatest reduction in fruit moth injury, resulting in fruit that was 25 per cent worm free. Biological studies carried on during this year indicated that the greater part of the injury apparent on the quinces at picking time had occurred during a period of about 6 weeks prior to ripening. Inasmuch as the last spray was applied 4 weeks before harvest, the quinces were unprotected during a considerable part of this critical period.

In the experiments of 1935, two treatments were employed and each was replicated 16 times. The oil-nicotine mixture employed in 1934, which consisted of 1½ gallons of summer oil and ⅔ pint of nicotine sulfate in 100 gallons of water, was again used. The second treatment consisted of one pint of nicotine and one pint of sulfated alcohol[3] to 100 gallons of water. During the interim between August 3 and September 16, five applications of each material were made. The treatments were applied about 10 days apart and the last occurred about 2 weeks before the first of the quinces were picked. The oil-nicotine treatment, which proved significantly better than nicotine and sulfated

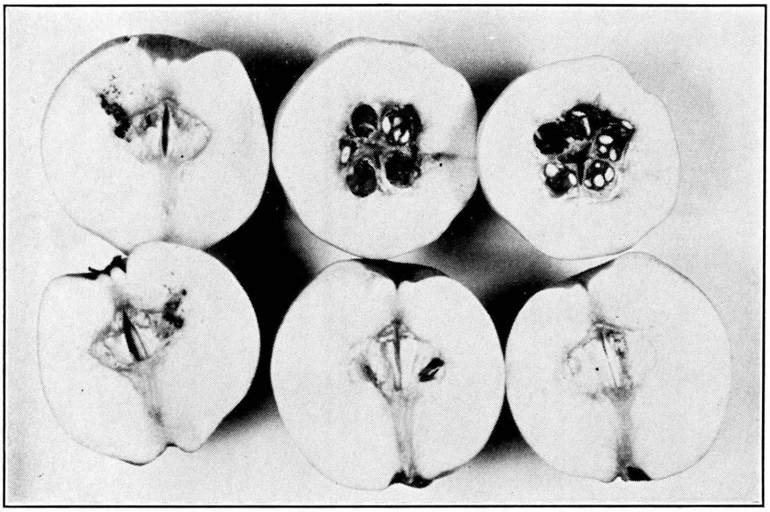

Fig. 7.—Spraying with lead arsenate and summer oil in 1931 yielded a fair degree of protection to quinces

alcohol, resulted in quinces that were 70 per cent clean; whereas untreated quinces in the same neighborhood were almost 100 per cent wormy. In considering this result, it should be pointed out that weather conditions in 1935 may have been a factor which rendered the fruit moth more easily controlled by the use of sprays. This thought presents itself because codling moth was much more easily controlled in this same area than it had been for several seasons. It should be borne in mind also that the fruit moth population in Ottawa County has been reduced during recent years through the activity of parasites.

PARASITES AND THEIR UTILIZATION IN CONTROL

PARASITE IMPORTATIONS

A record of the first attempt to introduce *Macrocentrus ancylivorus* Roh. into Lawrence County in 1927 has been reported (16). Subsequent studies indicated that this parasite was present in very small numbers in southern Ohio at the time the first colony was released; consequently, no further introductions were made at that time.

[3]This material is a sulfated alcohol composition, the value of which for use in spray formulae has been discovered recently by the Pest Control Division of the Grasselli Chemical Company.

Extensive work in colonizing *M. ancylivorus* in Ohio was not begun until 1930 (5, 7, 9, 10, 11), at which time various interested organizations and private individuals in Ottawa County subscribed a fund of $1000 to be used for that purpose. This work made possible the liberation of 6156 individuals of this species in Ottawa County. In addition to these introductions, nine colonies of adult parasites were released in the State by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture.

In 1932 a formal cooperative agreement was entered into with that Bureau, with Dr. H. W. Allen in immediate charge of the Federal aspects of the work. This agreement remains in effect, and it is due in large measure to this combined effort that the encouraging results in parasite colonization and establishment in the State have been obtained. A record of all liberations of *M. ancylivorus* in Ohio, which total approximately 25,000 individuals, is shown in Table 6.

TABLE 6.—Colonization of *Macrocentrus ancylivorus* Roh. in Ohio

County	Year of colonization	Number of colonies	Approximate number of *M. ancylivorus* released
Ashland	1932	1	250
Ashtabula	1932	2	500
Belmont	1931	1	500
Butler	1932	1	500
Columbiana	1931	1	500
Cuyahoga	1931	1	500
Cuyahoga*	1935	2	375
Darke*	1935	1	265
Erie	1930	1	400
Erie	1931	2	1000
Fairfield	1931	1	500
Fairfield	1932	1	250
Franklin	1930	1	300
Franklin	1932	1	250
Hamilton	1930	2	600
Hamilton*	1935	1	150
Holmes*	1935	1	234
Knox	1931	1	500
Lawrence*	1927	1	70
Lawrence	1930	1	500
Lawrence	1932	3	1050
Lake	1930	1	500
Lake	1932	1	250
Licking*	1933	1	140
Lorain	1930	2	1000
Lorain	1934	3	850
Meigs	1932	1	250
Montgomery	1932	1	250
Montgomery*	1933	1	132
Muskingum*	1935	2	500
Ottawa	1930	1	800
Ottawa*	1930	8	6000
Ottawa	1931	2	1000
Ottawa	1932	1	350
Ross	1931	1	500
Ross	1932	1	250
Stark*	1935	2	400
Summit	1931	1	500
Wayne	1931	2	1000
Wayne	1934	3	850
Wayne*	1934	1	120
Wayne*	1935	2	173
Total	....	65	25,009

*These parasites were reared at Wooster. All others were shipped to Ohio as adults from the Federal laboratory in New Jersey.

An additional advantage of the Federal cooperation is that it has been possible to secure colonies of parasites recently imported from the Orient, Australia, and Europe for colonization in Ohio. These species are indicated in Table 7.

TABLE 7.—Colonization of Foreign Parasites

Species released	County	Number of colonies	Number released	Year
Ascogaster quadridentata Wesm.	Ottawa	1	442	1932
Trichogramma euproctidis Gir.	Lorain	1	44,100	1932
Trichogramma euproctidis Gir.	Lake	1	34,000	1932
Periseriola angulata Mues.	Ottawa	1	487	1932
Bassus diversus Mues.	Ottawa	1	194	1934
Bassus diversus Mues.	Summit	1		1934
Dioctes molestae Uchida	Ottawa	4	2,150	1934
Dioctes molestae Uchida	Clermont	1		1934
Dioctes molestae Uchida	Lorain	2		1934
Dioctes molestae Uchida	Lake	1		1934
Dioctes molestae Uchida	Erie	1		1934
Dioctes molestae Uchida	Lawrence	1		1934
Dioctes molestae Uchida	Wayne	1		1934
Dioctes molestae Uchida	Summit	1		1934
Elodia flavipalpis Ald.	Summit	1	2	1934
Pristomerus vulnerator Panz.	Summit		47	1934
Bassus conspicuus (Wesm.)	Summit		6	1934

The colony of *Ascogaster quadridentata* Wesm. that was released in Ottawa County was obtained from Europe. However, it has been determined recently that *Ascogaster carpocapsae* (Vier.) and *Ascogaster quadridentata* Wesm. are synonymous. In Ohio this species is a common parasite of the codling moth and frequently has been taken on the fruit moth.

Bassus diversus Mues. and *Dioctes molestae* Uchida were both obtained from Japan. Six specimens of the latter species were recovered in Wayne County a few weeks after the colony was released there in 1934, but none were obtained in 1935 and it is questionable whether it has become established. *Bassus diversus* has not been recovered.

Periseriola angulata Mues. was obtained from Australia. It is a parasite that attacks the pupal stage of its host and, because of the difficulty with which fruit moth pupae are collected, no reliable information concerning the establishment of this species has been secured.

Trichogramma euproctidis Gir. is a very small insect which attacks the eggs of its host. It will be noted from Table 7 that 44,100 adults of this parasite were released in an orchard in Lorain County. Later in the season, in order to determine whether this insect was breeding in this orchard, a large number of fruit moth eggs which had been deposited on strips of cellophane were attached to the branches of the peach trees. After a few days these eggs were examined but none were found which had been attacked by the parasites. It was assumed, therefore, that the attempted introduction had failed.

PARASITIZATION IN NORTHERN OHIO

OTTAWA COUNTY

It will be noted in Table 6 that Ottawa County, which has nearly four times as many bearing peach trees as any other county in the State, received the greatest number of parasites. Before the first colony of *M. ancylivorus* was liberated in 1930, this parasite had never been taken in the area, although nine collections of peach twigs infested with fruit moth larvae had been tested for the presence of this species. In the latter part of the summer, however, after nine colonies had been released, the imported species was recovered in considerable numbers in nearly all orchards where parasites were placed. One peach twig collection taken in August, yielded 45 *M. ancylivorus*, three other parasites, and eight fruit moths, which is equivalent to a parasitization of 80 per cent by *M. ancylivorus* alone.

In 1931 the introduced species multiplied and spread rapidly. Four twig collections taken in two orchards which were three-fourths of a mile from the nearest colonization center were 80.7 per cent parasitized and *M. ancylivorus* accounted for 69.6 per cent of the total parasitization. In 1932 it was taken in each of the 16 orchards studied and was present in greater numbers than any other species. In an orchard located 4 miles from the nearest colony, which was established in 1930, this parasite was reared from 42 per cent of the larvae taken in a July collection. Native parasites were active also, with the result that 92.5 per cent of all fruit moth larvae collected during August 1932 was destroyed by parasites and the average monthly parasitization during the summer was 71.7 per cent. The infestation in Elberta peaches was distinctly lower than in 1931 and the reduction could only be attributed to the effectiveness of parasites. During 1933 and 1934 the percentage of parasitization continued high and the fruit moth infestation continued to fall. In 1935 the introduced species constituted 91 per cent of all parasites taken in the county. Two twig collections in one orchard yielded 1215 parasites and only 75 moths. Moreover, 95 per cent of the parasites obtained was *M. ancylivorus*. Many of the colonies of this species that were released in other parts of Ohio that year were obtained in this county.

The parasite records of all species of parasites taken in Ottawa County in June, July, and August during the past 7 years have been compiled in Table 8 to show the average parasitization for each successive year. This table represents an average of approximately 21 collections each year and a total of over 4100 parasite specimens.

TABLE 8.—Percentage Parasitization by all Parasite Species in Ottawa County

Month	1929	1930	1931	1932	1933	1934	1935
June	1.7	8.4	17.1	38.1	25.5	50.9	67.6
July	7.0	34.8	51.2	84.6	71.1	87.1	91.0
August	....	39.9	76.4	92.5	96.2	33.3	....
Average	4.3	27.7	48.2	71.7	64.3	57.1	79.3

It will be seen in Table 8 that parasitization built up rapidly after *M. ancylivorus* was introduced, until a peak was reached in 1932. In 1933 and 1934 slight decreases occurred, but a new high was reached in 1935. It is interesting to note the attending decrease in fruit moth damage that occurred during this period. The infestation that has been recorded in a representative orchard in the county is shown in Table 9.

TABLE 9.—Infestation in Elberta Peaches

Orchard of W. C. Yule, Danbury, Ohio

1927	1928	1929	1930	1931	1932	1933	1934
0.5	13.3	....	21.2	50.1	14.1	12.6	3.4

The infestation record shown in Table 9 probably is typical for Elberta peaches in Ottawa County for the period covered by this investigation, although some orchards of this variety were observed in which heavier losses were sustained. Varieties ripening later than Elberta were almost 100 per cent wormy in the most heavily infested orchards in 1929, 1930, and 1931.

It will be observed that the infestation in Mr. Yule's orchard continued to build up from 1927 until the peak was reached in 1931. The significant decrease in 1932 from that of 1931 synchronizes with the peak of parasitization. Since 1932 parasitization has continued high and fruit moth infestation has continued to decrease. No reliable infestation count was obtained in this orchard in 1935, but Mr. Yule reported that his peaches were free from worms.

WAYNE COUNTY

The performance of the fruit moth and its larval parasites in Wayne County has been similar to that in Ottawa County except that severe injury appeared a few years later and parasitization was slower in building up. The records of parasitization and infestation are shown in Tables 10 and 11.

TABLE 10.—Percentage Total Parasitization in Wayne County

Month	1930	1931	1932	1933	1934	1935
June	4.4	2.1	8.5	26.3	34.3	10.4
July	6.9	45.9	33.8	46.3	57.4	46.5
August	38.9	76.6	43.0	53.0	67.9	53.5
Average	16.7	41.5	28.4	41.9	53.2	36.8

TABLE 11.—Percentage Fruit Moth Infestation

Variety Orchard of the Experiment Station, Wayne County, Ohio

1930	1931	1932	1933	1934	1935
....	12.3	20.9	34.9	4.4	1.2

The record shown in Table 11 is the visible infestation occurring in Elberta peaches or other varieties that ripen at the time of Elberta. Since only visible injury was considered in this case, these infestation records should be increased by approximately one-third in order to compare them with those in Table 9.

Parasitization in this county has been due largely to the activity of *M. delicatus* although considerable numbers of *M. ancylivorus* were taken in 1934 and 1935. *Glypta rufiscutellaris* was active in Wayne County in 1931 and the drop in parasitization in 1932 was apparently due to the decreased activity of this species which has not been taken in any abundance since 1931. It will be noted in Table 10 that the percentage of larvae parasitized in 1935 was somewhat less than in 1934. In Ottawa County (Table 8) it was noted also that, after parasites had become sufficiently abundant to effect a substantial reduction in fruit moth injury, parasitization dropped off somewhat. Other records of insect parasitization indicate that when parasites become sufficiently abundant to reduce the host population appreciably the percentage of parasitization can be expected to fall at the time the host population is falling. Ultimately a balance is reached when the parasites can continue to exist but can depress the host population no further.

OTHER COUNTIES IN NORTHERN OHIO

The conditions of fruit infestation and larval parasitization that occurred in Ottawa and Wayne Counties fairly well represent the conditions over northern Ohio, although other counties were not studied so extensively. Parasitization has been high in Summit and Lake Counties and a significant drop in the infestation has occurred. In parts of Lorain and Cuyahoga Counties, however, parasites did not multiply to any appreciable extent until 1935. Meanwhile, fruit moth injury was severe although a significant reduction occurred in 1935. Two colonies of *M. ancylivorus* were released in Cuyahoga County in 1935. Fruit moth larvae collected from the generation that developed after the parasites were released were 63 per cent parasitized and 68 per cent of this parasitization was due to the introduced species. Three twig collections taken previous to the liberation of the parasites had yielded no *M. ancylivorus*.

The summary of the data obtained from all collections taken in ten northern Ohio counties (Ashland, Ashtabula, Columbiana, Cuyahoga, Erie, Lake, Lorain, Ottawa, Summit, and Wayne) is shown in Table 12.

TABLE 12.—Fruit Moth Parasitization in Northern Ohio

Month	1929	1930	1931	1932	1933	1934	1935
June	1.0	4.6	8.3	24.4	25.4	37.4	56.3
July	3.8	18.5	50.2	56.2	54.2	60.5	76.4
August	....	39.6	73.0	56.5	55.6	34.6	56.5
Average	2.4	20.9	43.8	45.7	45.1	44.2	63.1

It is evident that fruit moth parasites have resulted in a substantial saving to the peach growers of northern Ohio, and, although fluctuations in the amount of damage occurring from year to year can be expected, certainly the severe losses of 1929, 1930, and 1931 should not be repeated.

PARASITIZATION IN CENTRAL OHIO

Parasitization in the more centrally located counties has not been as favorable as in northern Ohio. *Macrocentrus ancylivorus* has been released in nine counties in this area—Belmont, Fairfield, Franklin, Knox, Licking, Montgomery, Darke, Muskingum, and Holmes. Subsequent examinations have been made in six of the nine counties listed and the introduced parasite has been recovered in five of them. In most cases only occasional specimens have been taken. In Licking County, however, a sufficient number of specimens were obtained to indicate that the species was becoming established. A small colony was released there in 1933, and a twig collection taken later that same year yielded 10 specimens. In 1934 a total of 32 parasites was obtained and 24 of them were *M. ancylivorus*. In 1935 twig injury was extremely light, and, although the orchard was visited several times during the season, at no time were twig-feeding larvae sufficiently abundant that a satisfactory twig collection could be obtained. From the larvae that were collected, one *M. ancylivorus* and eight *M. delicatus* were reared. It appears that the latter species is the more abundant. At the same time it would seem that parasites in general must be exerting a strong influence in suppressing the fruit moth population within the area; otherwise, the light infestation would not have prevailed.

In the other counties of central Ohio that were visited in 1935, the conditions were similar to those existing in Licking County. The fruit moth population was light throughout the season and but little fruit injury occurred. *M. delicatus* has continued as the predominating parasite species in this area and the fruit infestation has not been extremely high since 1928. A monthly summary of all parasite records obtained in the nine counties listed is shown in Table 13.

TABLE 13.—Fruit Moth Parasitization in Central Ohio

Month	1929	1930	1931	1932	1933	1934	1935
June...........	15.3	42.9	0	5.1	33.3	3.9	0
July...........	33.3	69.7	28.8	46.0	15.9	13.5	2.2
August........	66.7	....	47.3	41.2	36.6	14.7	26.9
Average...	38.6	56.3	25.4	30.8	28.6	10.7	9.7

A comparison of Tables 12 and 13 shows that the parasite population built up earlier in central Ohio than in northern Ohio. This is a logical result of the fact that the fruit moth appeared earlier in the central part of the State.

PARASITIZATION IN SOUTHERN OHIO

The fruit moth appeared in southern and central Ohio at approximately the same time and the parasitization that has occurred in the two areas has been somewhat similar. *Macrocentrus ancylivorus*, as shown in Table 6, has been released in Butler, Hamilton, Lawrence, Meigs, and Ross Counties, and, although it has been recovered in each county in which subsequent studies have been made, only a few specimens have been taken. Five colonies have been released in Lawrence County, but only two specimens have been taken since 1930. *M. delicatus* has been the predominating parasite species in this area and in 1935 accounted for 92.7 per cent of the total parasitization recorded. Only a few collections have been made in southern Ohio during the past few years, and, consequently, the record is not as complete as could be desired.

TABLE 14.—Fruit Moth Parasitization in Southern Ohio

Month	1927	1928	1929	1930	1931	1932	1933	1934	1935
June	13.3	21.9	12.9	29.6	3.8	12.1	....	52.3	31.0
July	23.3	17.1	23.9	59.6	30.8	60.3	....	17.2	12.9
August	29.7	17.7	30.0	....	90.9	....	72.2	....	93.8
Average	22.1	18.9	22.3	44.3	41.8	36.2	72.2	34.7	45.9

The heaviest fruit moth infestation recorded for southern Ohio occurred in 1928 when 90 per cent of the Elberta peaches in an orchard near Cincinnati was found to be wormy. During the following years the damage in this orchard gradually decreased and, although fluctuations have occurred, no very severe injury has been recorded. In 1935, the grower that experienced the severe losses in 1928 reported an infestation of 15 per cent in Elberta and Hale peaches.

INFLUENCE OF SPRAYS ON LARVAL PARASITIZATION

Small-scale experiments have been conducted during three consecutive seasons, beginning in 1933, to determine whether sprays applied to destroy the eggs and larvae of the fruit moth would influence the degree of parasitization of the larvae.

In 1933 a block of 30 5-year-old Elberta trees was divided into two plots. Nineteen trees were sprayed at 10-day intervals with a 2 per cent strength of summer oil, beginning when the first twig injury was noted and continuing as long as twig-feeding larvae could be found. The remaining 11 trees were not treated. Collections of twig-feeding larvae were made at weekly intervals from both blocks and in each case all of the larvae were taken that could be found readily on all of the trees.

One hundred and twenty-one moths and 132 parasites were reared from 10 twig collections taken in the sprayed plot, and the average parasitization of the 10 samples was 65 per cent. Ten collections from the untreated plot yielded 150 moths and 186 parasites, and the average parasitization was 66.5 per cent. It will be noted that the sprayed plot yielded the smaller number of larvae even though it contained a larger number of trees.

In 1934 a similar experiment was conducted in duplicate. The block of Elberta trees described above and another block of 90 4-year-old trees were each divided into two plots. One plot in each block was sprayed at 10-day intervals with 1½ gallons of a summer oil and ⅔ of a pint of nicotine sulfate in 100 gallons of water. The treatments were begun May 26 and completed August 13. The other plot in each block was not treated. Twig collections were made in the four plots at weekly intervals and all infested twigs that could be found readily were taken on each occasion. The records of parasitization obtained are summarized in Table 15.

These data also show that the sprays reduced the fruit moth population but that the parasitization remained approximately the same in the four blocks.

In 1935 a duplicate experiment was again conducted in much the same manner as in 1934. In this case, however, the sprays consisted of 2 pounds of lead arsenate, 8 pounds of zinc sulfate, and 8 pounds of hydrated lime in 100 gallons of water. Seven applications were made on the two treated plots. Eighteen twig collections were obtained in each plot and the data obtained are summarized in Table 16.

TABLE 15.—Influence of Sprays on Parasitization—1934

Block	Sprayed plots			Untreated plots		
	Moths	Parasites	Per cent parasitization	Moths	Parasites	Per cent parasitization
1	38	53	58.2	106	110	50.9
2	70	71	50.4	167	207	55.3
Total	108	124	53.4	273	317	53.7
Average	....	....	54.3	....	....	53.1

TABLE 16.—Influence of Sprays on Parasitization—1935

Block	Sprayed plots			Untreated plots		
	Moths	Parasites	Per cent parasitization	Moths	Parasites	Per cent parasitization
1	31	37	54.4	36	70	66.0
2	68	48	41.4	220	137	38.4
Total	99	85	46.2	256	207	44.7
Average	....	....	47.9	....	....	52.2

The records presented in Table 16 indicate that the lead arsenate sprays may have reduced parasitization. This corresponds in a general way to the records obtained by Cox and Daniel (3) in the case of the codling moth parasitization. The differences are much less than those obtained in New York, but, of course, different parasite species are involved. The predominating fruit moth parasite at Wooster is *Macrocentrus delicatus*; whereas Cox and Daniel were working with the codling moth parasite, *Ascogaster carpocapsae.*

PARASITIZATION OF FRUIT-FEEDING LARVAE

Occasional specimens of *Macrocentrus ancylivorus*, *M. delicatus*, and *Glypta rufiscutellaris* have been reared in Ohio from fruit moth larvae found feeding in peach fruit. However, parasitization by these species may have occurred while the larvae were feeding in twigs, and later the same larvae may have migrated to fruits.

A collection of fruit moth larvae taken from quince fruit in 1932 yielded 24 specimens of *Ascogaster* sp., equivalent to a parasitization of 3.6 per cent.

In 1933 a number of specimens of *Goniozus columbianus* were reared from larvae taken from the fruit of peach.

ALTERNATE HOSTS OF FRUIT MOTH PARASITES

Some species of the parasites that attack the Oriental fruit moth in Ohio will attack other insects as well. These are termed the alternate hosts. *Macrocentrus ancylivorus* and *Cremastus minor*, two of the more common fruit moth parasites, were reared from both the ragweed borer, *Epiblema strenuana* Walk., and the strawberry leafroller, *Ancylis comptana* Froel. *Macrocentrus delicatus, Glypta rufiscutellaris*, and *Pristomerus oscellatus* have been reared in considerable numbers from the ragweed borer. *Dioctes obliteratus* is a common parasite of the grape berry moth, *Polychrosis viteana* Clem., in northern Ohio.

TABLE 17.—Fruit Moth Parasites Recorded in Ohio

Species	Order	Family
Admontia degeeriodes Coq.	Diptera	Tachinidae
Aenoplex betulaecola Ashm.	Hymenoptera	Ichneumonidae
Anachaetopsis tortricis Coq.	Diptera	Tachinidae
Apanteles aristoteliae Vier.	Hymenoptera	Braconidae
Apanteles epiontiae Vier.	Hymenoptera	Braconidae
Apanteles polychrosidis Vier.	Hymenoptera	Braconidae
Apanteles n. sp.	Hymenoptera	Braconidae
Ascogaster carpocapsae (Vier.)	Hymenoptera	Braconidae
Ascogaster quadridentatus Wesm.	Hymenoptera	Braconidae
Atrometus clavipes (Davis)	Hymenoptera	Ichneumonidae
Bassus cinctus (Cress.)	Hymenoptera	Braconidae
Bassus sp.	Hymenoptera	Braconidae
Calliephialtes grapholithae (Cress.)	Hymenoptera	Ichneumonidae
Campoplex tortricidis Cush.	Hymenoptera	Ichneumonidae
Campoplex sp.	Hymenoptera	Ichneumonidae
Cremastus carpocapsae Cush.	Hymenoptera	Ichneumonidae
Cremastus forbesii Weed	Hymenoptera	Ichneumonidae
Cremastus minor Cush.	Hymenoptera	Ichneumonidae
Cremastus tortricidis Cush	Hymenoptera	Ichneumonidae
**Dibrachys boucheanus* (Ratz.)	Hymenoptera	Pteromalidae
**Dibrachys cavus* (Walk.)	Hymenoptera	Pteromalidae
Dioctes molestae Uchida	Hymenoptera	Ichneumonidae
Dioctes obliteratus (Cress.)	Hymenoptera	Ichneumonidae
†*Ephialtes aequalis* (Prov.)	Hymenoptera	Ichneumonidae
Epiurus indagator (Cress.)	Hymenoptera	Ichneumonidae
Eubadizon sp.	Hymenoptera	Braconidae
Eubadizon pleuralis Cress.	Hymenoptera	Braconidae
Euderus n. sp.	Hymenoptera	Chalcididae
Eupelmus amicus Gir.	Hymenoptera	Eupelmidae
Glypta rufiscutellaris Cress.	Hymenoptera	Ichneumonidae
Goniozus columbianus Ashm.	Hymenoptera	Bethylidae
**Hemiteles tenellus* Say.	Hymenoptera	Ichneumonidae
Lixophaga mediocris Ald.	Diptera	Tachinidae
Lixophaga plumbea Ald.	Diptera	Tachinidae
Lixophaga variabilis Ald.	Diptera	Tachinidae
Macrocentrus ancylivorus Roh.	Hymenoptera	Braconidae
Macrocentrus delicatus Cress.	Hymenoptera	Braconidae
Macrocentrus instabilis Mues.	Hymenoptera	Braconidae
Macrocentrus pallisteri DeGant.	Hymenoptera	Braconidae
Macrocentrus sp.	Hymenoptera	Braconidae
Meterorus trachynotus Vier.	Hymenoptera	Braconidae
Microbracon politiventris (Cush.)	Hymenoptera	Braconidae
Microgaster mediocris Ald.	Hymenoptera	Braconidae
Microgaster ecdytolophae Mues.	Hymenoptera	Vipionidae
‡*Perilampus* n. sp.	Hymenoptera	Vipionidae
‡*Perilampus fulvicornis* Ashm.	Hymenoptera	Perilampidae
Pristomerus oscellatus Cush	Hymenoptera	Perilampidae
†*Proscus walshiae* (Ashm.)	Hymenoptera	Ichneumonidae
§*Trichogramma minuta* Riley	Hymenoptera	Ichneumonidae
		Trichogrammidae

*Both primary and secondary parasite.
†Pupal parasite.
‡Secondary parasite.
§Egg parasite.

TABLE 18.—The Relative Abundance of the More Important Fruit Moth Parasite Species Studied in Each County in 1935, Expressed in Percentage of Total Parasitization

County	*Macrocentrus ancylivorus*	*Macrocentrus delicatus*	*Cremastus minor*	*Cremastus forbesii*	*Glypta rufiscutellaris*	*Pristomerus oscellatus*	*Dioctes obliteratus*	Others
Cuyahoga	48.8	7.3	8.5	1.2	22.0	2.4	7.3	2.4
Erie	81.7	....	14.2	0.8	....	1.7	....	1.7
Lake	98.0	0.2	1.4	....	....	0.2	....	0.2
Lorain	68.6	0.8	10.2	....	6.8	11.0	1.3	1.3
Ottawa	91.1	0.2	4.9	0.9	1.6	0.1	0.4	0.6
Summit	93.2	4.3	....	....	0.8	1.7	....	....
Wayne	27.8	48.6	....	....	19.7	0.9	....	3.0
Holmes	....	....	....	....	66.7	33.3	....	....
Licking	6.7	53.3	....	....	40.0	....	....	....
Montgomery	....	100.0	....	....	....	....	....	....
Hamilton	....	57.1	19.0	....	19.0	....	....	4.8
Lawrence	1.1	97.1	....	....	....	....	....	1.7
Meigs	....	92.9	....	....	....	7.1	....	....
Average	39.8	35.5	4.5	0.2	13.6	4.5	0.7	1.2

These alternate hosts are all rather widely distributed in the State and should enable the parasites to carry over periods of scarcity of fruit moth larvae.

NATURAL ENEMIES OF THE FRUIT MOTH, OTHER THAN LARVAL PARASITES

The discussion of fruit moth parasitization up to this point has considered only those forms which attack the larval stage of the host. Undoubtedly, these constitute the most important group, but it is known that egg and pupal parasites also take their toll. Predators, no doubt, attack all four stages of the fruit moth and occasionally may destroy a sufficient number to have a significant influence on the population in an orchard.

Trichogramma minuta Riley, an egg parasite, has been taken in Ohio. Although no satisfactory record has been obtained of the relative numbers of fruit moth eggs destroyed by it, it may be sufficiently abundant at times to be of economic importance.

Two pupal parasites, *Proscus walshiae* (Ashm.) and *Ephialtes aequalis* (Prov.), have been taken in Ohio, but, owing to the difficulty with which pupae are collected in orchards, little information has been obtained on the abundance of pupal parasites. However, Nettles (13) has shown a record of pupal parasitization of 56 per cent in South Carolina.

Lady beetles are frequently abundant in Ohio peach orchards and, no doubt, destroy some fruit moth eggs and larvae. In 1930, a lady beetle was found feeding on a nearly grown fruit moth larva that had started a new entry into a peach twig. A few lady beetles were then captured and placed in cages with various sizes of fruit moth larvae. Two adults of *Adalia bipunctata* Linn. consumed 26 larvae in 4 days. One adult of *Coccinella novemnotata* Hbst. consumed 10 larvae in 5 days. Four adults of *Hippodamia tredecimpunctata* Linn., however, destroyed none of the fruit moth larvae enclosed with them.

Green lacewing flies are often numerous in Ohio orchards and may destroy a considerable number of fruit moth eggs.

Many larvae or pupae are sometimes destroyed by birds and possibly by fungous diseases, but the identity of neither has been determined.

THE FRUIT MOTH–NATURAL ENEMY RELATIONSHIP

The habits of the fruit moth make it peculiarly subject to attack by larval parasites in the early part of the growing season. The first two broods of host larvae feed chiefly in peach twigs where conditions are favorable for parasite activity. The parasite population builds up rapidly during this period with the result that the third brood of fruit moth larvae, which otherwise does most damage, is greatly reduced. This brood, however, is largely protected from parasites because the larvae feed chiefly in fruit rather than in twigs. Consequently, the fourth brood becomes sufficiently large to produce a considerable overwintering population. This again results in an abundant supply of host material for the parasites the next year at the time when they are most effective, and the cycle of destruction is repeated.

It should be remembered that to the toll taken by larval parasites must be added that taken by other natural enemies. The list of parasites and predators with which the fruit moth must contend is rather formidable, and, in order to become a severe pest, it must overcome a tremendous handicap. On the other hand, the fruit moth has great reproductive ability, as has been emphasized in an earlier paragraph.

It is known that populations of the fruit moth and of parasites may be influenced, either directly or indirectly, by extreme weather conditions. It is to be expected, therefore, that the cycle of parasitization should be interrupted at times and that fluctuations in fruit moth damage should occur. Nevertheless, the extreme fruit moth infestations that have been experienced should not be repeated.

PRESENT STATUS OF THE FRUIT MOTH IN OHIO

It is no uncommon experience in northern Ohio to find rather heavy fruit moth populations in the early part of the season, but during recent years these populations have diminished rapidly by the time Elberta harvest arrived. In 1935 four orchards were visited in which not more than 2 per cent of the Elberta peaches was injured. Several growers have made the statement that they no longer consider the fruit moth a problem in their community. In a few rather isolated areas only was injury at all severe last season.

This condition is due chiefly to the activity of parasites. *Macrocentrus ancylivorus*, which was introduced into northern Ohio first in 1930 and has been further colonized and distributed in more recent years, has multiplied so rapidly that it has become a predominating parasite species throughout most of northern Ohio and has been largely responsible for the reduction of fruit moth damage in that area.

This parasite has not been so effective in central and southern Ohio. However, indigenous parasite species, especially *Macrocentrus delicatus*, have become sufficiently active that fruit moth damage has not been severe.

Inasmuch as the best spraying schedules that have been devised for the control of the fruit moth have not consistently reduced the injury in Elberta peaches by more than 50 per cent and since such spraying schedules have involved considerable time and expense, the infestation should be relatively high for such a schedule to be economically advisable. Consequently, no spraying program for the control of this insect on peaches is recommended.

Fruit moth larvae developing in quinces, however, are largely protected from parasites, and, if no special control measures are employed, the infestation usually becomes so severe that the fruit is almost worthless. Although experimental sprays for quinces have not proven completely satisfactory, it is believed that the oil-nicotine program previously discussed can be relied upon to give a considerable degree of control. Moreover, it is likely that some of the growers who have viewed the results obtained may adopt the schedule as a commercial practice.

SUMMARY

The time of emergence of spring brood Oriental fruit moths varies with temperature but corresponds with the blooming period of the peach. Both appear successively later in a definite progression across the State from southern Ohio northward.

In cultivated peach orchards in Ohio considerable numbers of both winter and summer cocoons have been found on the ground. Therefore, orchards in which frequent cultivation is practiced have an advantage over those which are not tilled. On the other hand, the fact that some of the fruit moth parasites attack weed infesting larvae should be borne in mind. Packing houses and used baskets frequently harbor many hibernating larvae and these should be given attention during periods of fruit moth abundance.

In Ohio orchards fruit moth larvae have been found feeding in the fruits of peach, apple, quince, pear, and plum and in the twigs of peach, apple, and sweet cherry. They have also been found in the growing tips of a rose bush.

Larval mortality varies with the hardness of the peach fruit in which the larvae feed. Natural mortality is low early in the season when the peach is growing rapidly, high in midseason while the stone is hardening, and low again when the peach swells rapidly before ripening.

Eight infestation counts made in a particular orchard during three successive seasons have shown an unequal but consistent fruit moth distribution across the orchard. One side was consistently most heavily infested. Such peculiar distributions have not been adequately explained.

In experimental spraying work a combination of summer oil and nicotine has uniformly given best results. Five applications made to quinces during the latter part of the season produced a large percentage of marketable fruit in 1935; whereas unsprayed quinces in the immediate vicinity were almost a total loss. Experience has shown that any spraying program for fruit moth control must be timed with precision if the greatest good is to result.

Approximately 25,000 individuals of *Macrocentrus ancylivorus* have been released in Ohio. This parasite species has been multiplying rapidly in northern Ohio and has been largely responsible for a significant reduction in fruit moth injury in that part of the State. Eight species of foreign parasites have been introduced into Ohio but as yet none are known to have become established. Native parasite species and other natural enemies have become sufficiently abundant in central and southern Ohio to suppress the fruit moth population. Several of the more important fruit moth parasites are known to attack the ragweed borer and the strawberry leafroller, both of which are generally distributed in Ohio. These parasites, therefore, should be able to survive during periods when fruit moth larvae are scarce.

Fruit moth damage in Ohio, when the State as a whole is considered, probably reached a peak in 1931. Since that time, due chiefly to the activity of parasites, the injury has been decreasing and in 1935 was relatively light in most orchards.

Because of the influence of extreme weather conditions on the populations of fruit moths and parasites, fluctuations in fruit moth damage may be expected to occur from year to year. Nevertheless, it is thought that the extreme infestations that were experienced during earlier years of fruit moth occupancy in Ohio are not likely to be repeated.

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