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BIOLOGICAL CONTROL OF THE ORIENTAL FRUIT MOTH

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BULLETIN No. 635

BIOLOGICAL CONTROL OF THE ORIENTAL FRUIT MOTH

DERRILL M. DANIEL, JAMES COX, AND AUBREY CRAWFORD

ABSTRACT

The importance and distribution of the oriental fruit moth (*Grapholitha molesta* Busck) in western New York from 1927 to 1932 are the primary considerations of this bulletin. By the end of 1931 practically all of the commercial peach area of western New York was infested. Considerable injury to apples has been noted and, generally speaking, quinces are 100 per cent infested.

The outlook in regard to peach culture has undergone a decided improvement since the establishment of the parasite *Macrocentrus ancylivorus*. This parasite has taken a steadily increasing toll of the twig-infesting larvae since its introduction, the percentage of parasitism rising from 6.63 in 1928 to 25 in 1932.

Parasitism by indigenous species varied considerably from year to year, due chiefly to fluctuations in the abundance of *Cremastus minor* and *Glypta rufiscutellaris*. Coincident with the increasing parasitism by *M. ancylivorus* there was apparently a decrease in the population level of the fruit moth. In Niagara County the high point of damage was reached in 1929, when 59.89 per cent of the crop was infested with an estimated population of 18,901 larvae per acre. In 1932 these estimates showed only 8,288 larvae per acre with 14.01 per cent of the crop infested. This represents a reduction of 56.4 per cent in the population per acre. It is believed that similar results may become apparent in the other infested counties when the parasites become firmly established.

An account is given of the technic developed for the rearing of both hosts and parasites.

INTRODUCTION

When the oriental fruit moth (*Grapholitha molesta* Busck) was discovered in western New York in 1926, it had been present in the United States for at least 10 years. During that time it had spread steadily from the original point of infestation at the city of Washington until it had appeared in most of the peach-growing districts of the eastern United States. In many cases in those areas in which it had become firmly established, from 75 to 90 per cent of the total peach crop was infested. Experiments by numerous investigators on varied means of control had been carried on, but all with the exception of the use of parasites gave little encouragement that the pest could be effectively combated by ordinary methods.

The wholesale breeding and distribution of parasites appeared to be the most hopeful means of gaining ascendancy over the oriental fruit moth, and it seemed highly desirable to test the feasibility of the utilization of parasites in the control of that pest in the peach districts of New York. Studies conducted in 1927 in Chautauqua County showed only two species of parasites, namely, *Ascogaster carpocapsae* (Viereck) and *Glypta rufiscutellaris* Cresson, to be working on the fruit moth and that only very negligible parasitism resulted. It has since been shown that these two species are very erratic in the degree of control which they exert. The need of colonization of some more promising species was indicated.

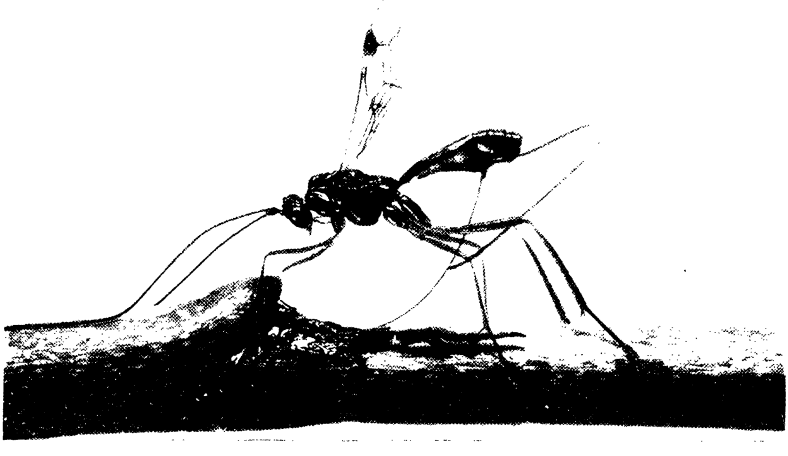

FIG. 1.—THE PARASITE *Macrocentrus ancylivorus* IN THE ACT OF OVIPOSITION.

Southern New Jersey at that time showed the highest parasitism of any section of the United States, and *Macrocentrus ancylivorus* Rohwer (Fig. 1) was by far the most effective species in that area. Accordingly, in 1928, transfer and colonization of this species were begun in western New York. A comprehensive report of the details of the investigations has been published in Technical Bulletin No. 187 of this Station. The object of the present paper is to review the efforts undertaken to distribute parasites as well as to describe the present status of the work relative to the biological control of the oriental fruit moth in western New York.

ABUNDANCE AND SPREAD OF ORIENTAL FRUIT MOTH IN WESTERN NEW YORK

Following the appearance of the oriental fruit moth in Niagara County, the species, thru natural spread and large shipments of infested peaches from southern states to cities, towns, and villages has become well seeded in the entire peach belt of western New York. The heart of the industry embraces an area approximately 100 miles long and 25 miles wide and is parallel with the shore of Lake Ontario (Fig. 2). In the counties devoted to peach culture there are about 2,655,000 trees.

In 1928, the oriental fruit moth was just coming into prominence as a peach pest in Niagara County. The infestation centered about Lewiston and Youngstown on the Niagara River and extended eastward to Ransomville. Counts made in two orchards in this area showed that an average of 15 per cent of the fruit was injured. Fig. 2 shows the approximate limits of the commercial damage in 1928 and subsequent years. The infestation was limited on the south by the boundary of the commercial peach area, on the north by Lake Ontario, and on the west by the Niagara River. Therefore, the only direction of spread of the pest was eastward.

Practically all of Niagara County showed more or less infestation by the pest at the end of 1929. Somerset and Gasport marked the approximate eastern limits of the infestation. However, the most severe injury was still noted in the western portion of the county. In the area about Lewiston, Youngstown, and Ransomville, the fruit injury varied from 38.82 per cent to 73.52 per cent in individual orchards and averaged 59.89 per cent. This area of severe damage coincided with the limits of the area infested the previous year. The

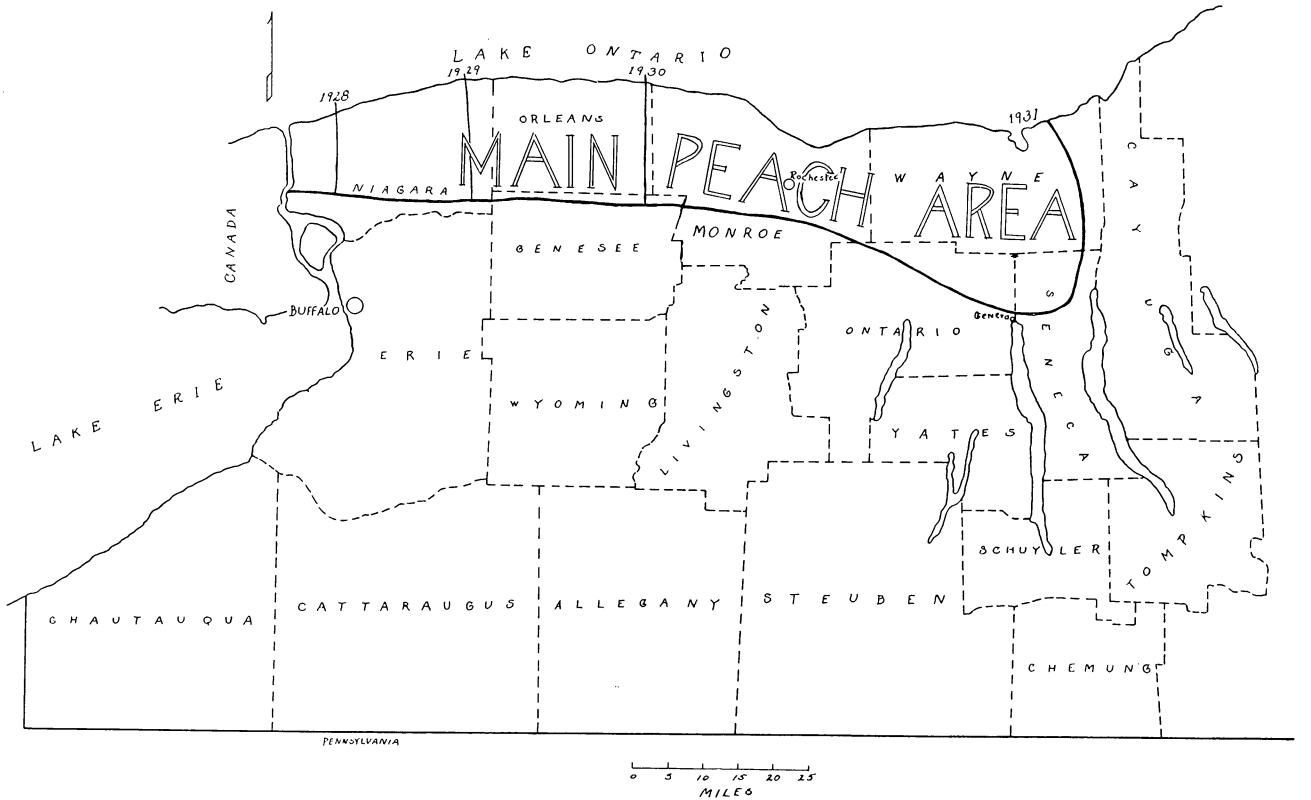

FIG. 2.—MAP OF WESTERN NEW YORK SHOWING SPREAD OF THE ORIENTAL FRUIT MOTH.

eastern portion of the county was marked by scattered, fairly light infestations.

In 1930, the pest spread eastward from Niagara County over practically all of Orleans County and was found in very small numbers in widely separated orchards in Monroe and Wayne counties. There was also an orchard at Hector, in Schuyler County, and another at Geneva, in Ontario County, which displayed infestation by the pest. The limits of commercial damage, however, were confined to Niagara and Orleans counties. In Niagara County the percentage of fruit injured varied from 4.57 to 48.58 in individual orchards. The average infestation for 19 orchards, distributed over the entire county, in which counts were made was 15.61 per cent. It was found that the higher infestations, i. e., the worst damage were still confined to the western portion. The average infestation of 15.61 per cent for the county was considerably below the average of 59.89 per cent for the preceding year. In Orleans County, altho the pest was well distributed over the entire peach area, the infestation was not severe and consequently over the county as a whole the injury was rather light. As stated above, the infestation in the remainder of the commercial peach area of western New York was negligible.

The eastern distribution of the pest and the spread from local points brought Monroe and Wayne counties into the area of continuous infestation in 1931. Altho the pest was present in almost every orchard in these two counties, the injury was negligible, and the average infestation was estimated to be less than 2 per cent of the crop. In Orleans County the percentage of fruit injured varied from 5.94 to 8.03 in individual orchards. The average infestation was approximately 7 per cent. In Niagara County the percentage of fruit injured varied from 2.33 to 25.85 in individual orchards. The average infestation for the entire county was 13.43 per cent. This average was only slightly lower than that of the previous year, but a more encouraging sign was the fact that most of the higher percentages of injury were found in the eastern portion of the county instead of in the western portion, as had been the case in previous years. This movement of the center of heavy injury from the western to the eastern portion of the county was a hopeful factor since it indicated that the parasites were beginning to exert a marked influence on the population level of the pest. The parasites were first established in the western portion of the county (Fig. 3), and

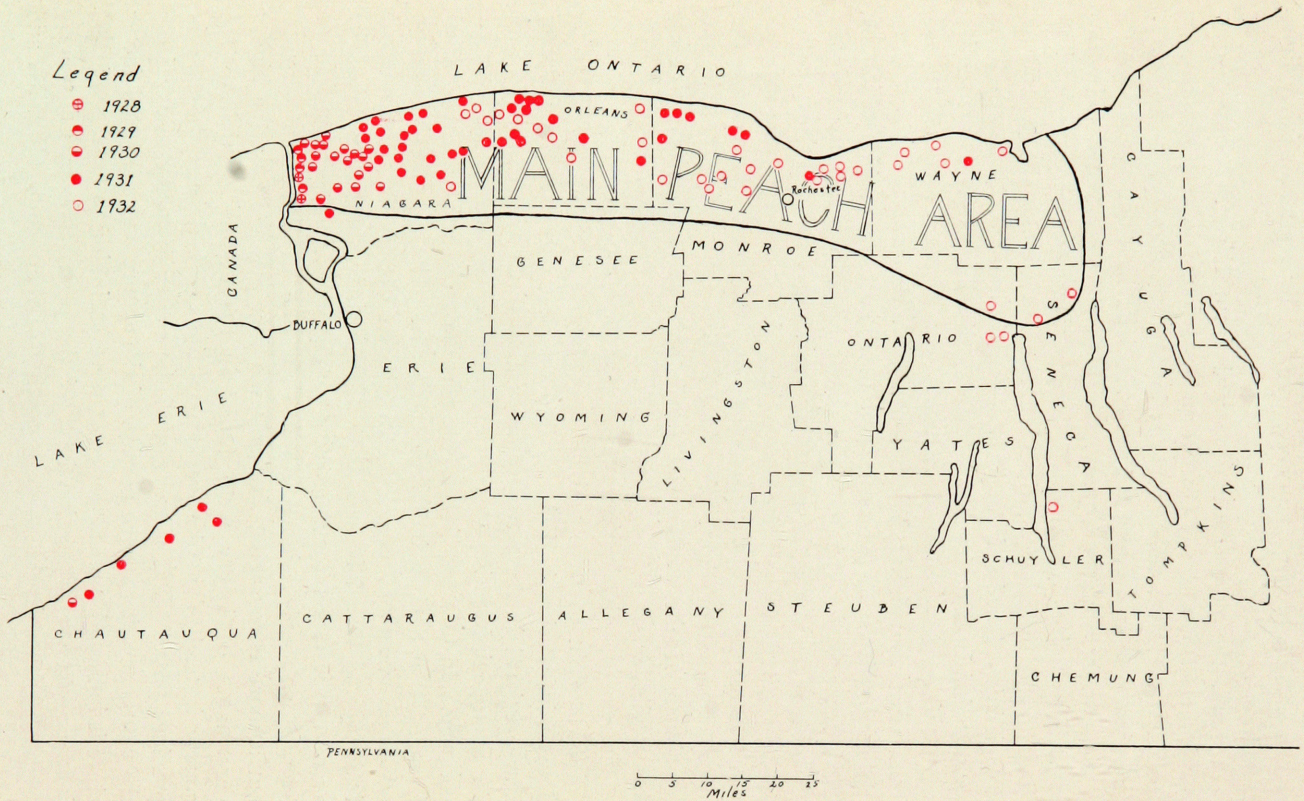

FIG. 3.—MAP OF WESTERN NEW YORK SHOWING LOCATIONS OF COLONIES OF *Macrocentrus ancylivorus*.

consequently, if any benefits were to result, they should first become apparent in that section.

By the end of 1931 the oriental fruit moth had infested practically all of the important peach areas in western New York, including Niagara, Orleans, Monroe, and Wayne counties. In 1932, Orleans, Monroe, and Wayne counties showed increased damage generally and the pest established itself in all orchards which had heretofore betrayed no evidence of its presence. In Orleans County the average infestation was about 32 per cent; in Monroe County, it was about 14 per cent; and in Wayne County, it was about 9 per cent. In Niagara County in 1932, the percentage of fruit injured varied from 8.07 to 25.08 in individual orchards. The average infestation for the entire county was 14.01 per cent. The encouraging trend of the eastward movement of the higher infestations noted in 1931 was more pronounced in 1932. In the western portion of the county, where the parasites were first established and consequently had had the longest time for parasitizing the fruit moth larvae, the average infestation was 9.14 per cent of the crop; while the eastern portion, where parasites had not been established for so long a time, showed an average infestation of 18.8 per cent.

Whether the western portion of Niagara County will continue to show reductions of infestation in the future is, of course, a matter of conjecture; but it now seems probable that, in the future, growers in the eastern portion of the county may reasonably expect continued improvement, at least to the extent of that shown in the Lewiston–Youngstown area. While the oriental fruit moth will probably exist as a permanent pest, the prospects are that the periods of severe damage will be less frequent and that the injury will not reach as severe proportions as heretofore.

INJURY TO OTHER FRUITS

A factor of major importance in western New York is the occurrence of the fruit moth in apples in appreciable numbers. Counts were made in 1931 in three apple orchards near Youngstown (Table 1). The figures given do *not* represent percentages of injury to apples, but are the proportions of oriental fruit moth to codling moth larvae. The first orchard, Wealthy apples bordered by peach plantings on one side, showed that 19.09 per cent of the caterpillars existing within the fruit were oriental fruit moth larvae. The

second orchard, Baldwin apples bordered by peach orchards on two sides, showed that 11.5 per cent of the caterpillars found were oriental fruit moth larvae. The third orchard, Baldwin apples interplanted with peaches, displayed the fact that 7.3 per cent of the caterpillars within the apples were fruit moth larvae. In these counts the larvae were cut out of the fruit at the time that the grower was harvesting the crop.

TABLE 1.— ORIENTAL FRUIT MOTH IN APPLES IN 1931.

ORCHARD	TOTAL LARVAE	NUMBER CODLING MOTH LARVAE	NUMBER ORIENTAL FRUIT MOTH LARVAE	PERCENTAGE ORIENTAL FRUIT MOTH LARVAE
George Tower, Wealthy apples bordered by peaches on one side.....	198	160	38	19.09
Shippey, Baldwin apples bordered by peaches on two sides.....	278	246	32	11.50
B. Cothran, Baldwin apples interplanted with peaches.....	150	139	11	7.30

In addition to the injury to peaches and apples, quinces have suffered severely from the ravages of the pest. Generally speaking, quinces in Niagara County were 100 per cent infested. The question naturally arises as to why the parasite *Macrocentrus ancylivorus,* which has apparently been successful in reducing infestations in peach orchards, is unable to exert appreciable control in quince orchards. In this connection it should be pointed out that the parasite in order to be effective must be able to reach the fruit moth larvae with its ovipositor. The parasite egg must be laid directly within the body of the host larva. The female parasite is usually able to parasitize a caterpillar when it is burrowing in a twig, but when it burrows into a fruit it usually goes so deep into the flesh that the parasite is seldom able to reach it with her ovipositor. In a peach orchard, larvae of the fruit moth burrow in the twigs during the spring and most of the summer. But in a quince orchard only a few larvae in the early spring burrow in the twigs. During the remainder of the season practically all of the oriental fruit moth caterpillars live within the fruit and consequently escape parasitism. For that reason the parasite has been unable to exert appreciable influence on the population of the oriental fruit moth in quince orchards.

In an effort to utilize parasites in checking the ravages of the fruit moth in quinces, 1,000 individuals of *Ascogaster carpocapsae* (Viereck), a common parasite of the codling moth, were liberated in a small block of quinces in 1932. This parasite lays its eggs within the egg of the fruit moth, both eggs hatch and the parasite larva kills the fruit moth larva when its cocoon is formed. However, repeated collections thruout the summer failed to show any increase in parasitism by A. *carpocapsae*. It now seems probable that apple trees exert a specific attraction for this parasite, and that when the parasites are liberated in quince orchards they immediately seek nearby apple orchards.

In view of the above considerations it was decided to re-investigate the use of insecticides in the control of the fruit moth, particularly in quince plantings. Two experiments are now under way which should throw some light on this problem.

IMPROVEMENT OF OUTLOOK IN REGARD TO PEACH CULTURE

It became evident from work in other sections that common methods of control would not effectively reduce the population level of the oriental fruit moth. The obvious alternative was the utilization of parasites. Surveys conducted in 1927 indicated that no parasite of any consequence was present in western New York, therefore if parasites were to be utilized importations would have to be made from some other area. The searching for parasites in foreign lands was out of the question in so far as New York was concerned, so our efforts were necessarily limited to the United States. The obvious place to look for a promising parasitic species was in some of the sections in the United States which had been longest infested by the oriental fruit moth. Southern New Jersey was such an area. It was here that there had appeared a larval parasite, *Macrocentrus ancylivorus* Rohwer, which was particularly effective as a factor in the control of the oriental fruit moth. This parasite was selected, therefore, as the most promising species for introduction into western New York. The introduction and establishment of this species in western New York have been fully considered in other publications and need be only briefly treated here.

In 1928, two colonies of the parasite were established along the Niagara River in the midst of the original infestation in that area. In 1929, four more colonies were established in the same district. In

1930, 19 colonies were established in the western portion of Niagara County. In 1931, 41 colonies were established over the entire area of infestation in the four main peach counties of western New York, namely, Niagara, Orleans, Monroe, and Wayne. In addition five colonies were established in Chautauqua County. In 1932, 35 more colonies were distributed thru the same territory as well as in infested orchards in Ontario, Seneca, and Schuyler counties. Fig. 3 shows the location of these 106 colonies. Twenty of these colonies were liberated in cooperation with the Bureau of Entomology of the United State Department of Agriculture. The liberations of parasites were restricted to Niagara County for 3 years because of lack of sufficient infestation by the oriental fruit moth in other parts of the peach section. However, the eastward spread of the pest, as outlined previously, was followed rather closely with liberations of this parasite, as a comparison of Figs. 2 and 3 will clearly show.

So far as the individual grower is concerned, the chief advantage of the biological control method is that it is self-supporting; that is, it costs the individual grower nothing directly. On the other hand, it is very essential that the progress of an introduced parasite be followed by a technical worker for a number of years after colonization. This supervision is desirable in order to insure that the species introduced has actually become established as well as that an accurate determination may be made of the exact effect the parasite is exerting on the pest. It was not sufficient therefore that the parasite be colonized and then wait to see if any reduction of economic damage occurred. It was necessary that the activities and progress of the parasites after introduction be noted by careful rearings and dissections in such a manner as to furnish data demonstrating that any reduction in damage was due to the parasite and that there was little reason to suspect that the changes produced were caused by variations in any other factors.

In order to secure data of this sort the plan was followed of making weekly collections of infested peach twigs thruout the entire season in each orchard in Niagara County in which a colony of parasites was established. Such frequent collections were made necessary by the continuous presence thruout the greater part of the summer of the oriental fruit moth in a stage suitable for attack by the parasite. Limitations of labor made it necessary to restrict these weekly collections to Niagara County.

The following data, based on conditions in Niagara County, are

summarized from a detailed report[1] of the investigations from 1928 to 1931. Also, there is included a summary of the data for the 1932 season. Fig. 4 is a graphic representation of the data under

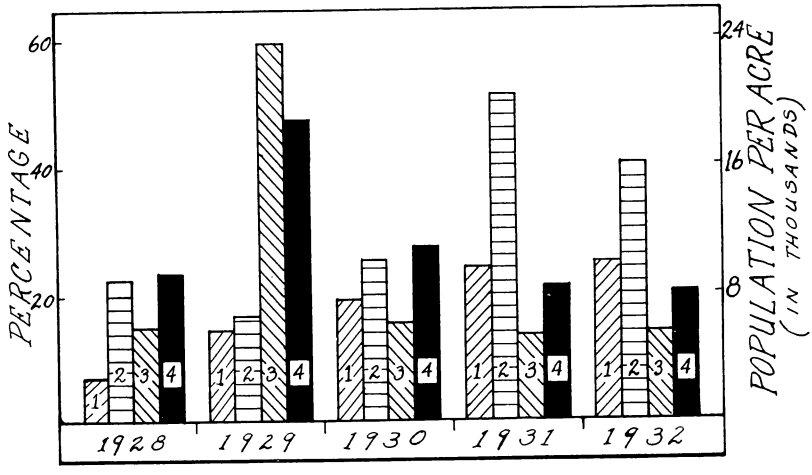

FIG. 4.—GRAPHIC SUMMARY OF PARASITISM AND FRUIT MOTH POPULATION IN NIAGARA COUNTY.

Column 1, percentage of parasitism by *M. ancylivorus* alone; column 2, total percentage of parasitism by all species of larval parasites including *M. ancylivorus;* column 3, percentage of fruit infestation by the fruit moth; column 4, calculated number of fruit moth larvae present per acre at harvest time. Columns 1, 2 and 3 read left; column 4, read right.

consideration. Columns 1 and 2 show, respectively, the percentage of oriental fruit moth larvae parasitized by *M. ancylivorus* and the total percentage parasitized by all species of larval parasites including *M. ancylivorus*. It will be seen that the percentage of parasitism by *M. ancylivorus* rose steadily each year. In 1928, it parasitized 6.63 per cent of all twig-infesting larvae collected in Niagara County; in 1929, 15.3 per cent; in 1930, 19.76 per cent; in 1931, 24.15 per cent; and in 1932, 25.0 per cent. It should also be pointed out that the total parasitism varied considerably from year to year, due chiefly to fluctuations in the abundance of *Cremastus minor and Glypta rufiscutellaris*. The total parasitism recorded was, for 1928, 22.1 per cent; for 1929, 16.5 per cent; for 1930, 24.15 per cent; for 1931, 51.35 per cent; and for 1932, 40.21 per cent.

It is obvious that, taken alone, percentage of parasitism of one stage of a pest as represented by the above figures may not neces-

[1] *New York State Agr. Exp. Sta. Tech. Bul. No. 187, 1932.*

sarily be a true indication of the situation. Numerous cases are on record where percentage of parasitism was high and still the pest in question was able to inflict tremendous losses. In the case of the oriental fruit moth, therefore, it was considered important to determine the population level of the pest and to correlate its abundance or scarcity with the recorded parasitism. Now, with the oriental fruit moth, probably the most accurate measure of the population level is found in the number of larvae present at harvest time. This may be found by examining all the fruit from several trees in certain representative orchards. From these fruit counts the probable number of larvae per acre may be calculated with reasonable accuracy. Table 2 gives the average number of fruits per tree, the average number of fruits per acre, the average percentage of fruit infested, and the average number of fruit moth larvae per acre for the years 1928 to 1932, inclusive.

TABLE 2.— ORIENTAL FRUIT MOTH INFESTATION IN NIAGARA COUNTY.

YEAR	AVERAGE NUMBER OF FRUITS PER TREE	AVERAGE NUMBER OF FRUITS PER ACRE	AVERAGE PERCENTAGE OF INFESTATION	AVERAGE NUMBER OF LARVAE PER ACRE
1928	447	53,652	15.00	9,468
1929	263	31,560	59.89	18,901
1930	593	71,160	15.61	11,108
1931	532	63,814	13.43	8,570
1932	493	59,160	14.01	8,288

The percentage of fruit infestation cannot usually be taken as an accurate indication of the population level of the oriental fruit moth because this figure is influenced considerably by the size of the crop (number of fruits per acre). For example, in 1929, 59.89 per cent of the crop was infested. Then, in 1930, the size of the crop was 2¼ times as large as in 1929. Now if no other factor except the size of the crop were operating, the percentage of infestation in 1930 should have been 26.6 (59.89 ÷ 2.25). However, the actual percentage of infestation in 1930 was 15.61, therefore it is obvious that factors other than the size of the crop were operating on the population level of the oriental fruit moth.

If the actual number of larvae per acre is determined, the resulting figure is one which should not be influenced by the size of the crop. because obviously the number of larvae per acre cannot be limited by the size of the crop unless the infestation is so large or the crop

so small that a shortage of food results. It appears, therefore, that the number of larvae present per acre at harvest time may safely be correlated with the degree of parasitism.

Fig. 4 shows graphically in columns 3 and 4, respectively, the percentage of fruit infestation and the calculated number of fruit moth larvae per acre. The calculated number of larvae per acre in Niagara County in 1928 was 9,468; in 1929, 18,901; in 1930, 11,108; in 1931, 8,570; and in 1932, 8,288. It is realized that the above figures are at best an approximation, but it is felt that they are sufficiently accurate to indicate the trend of developments. It will be seen that following the high point of 1929 there has been a decided reduction in the population level of the pest; in fact, the drop from 18,901 to 8,288 larvae per acre constitutes a diminution of 56.4 per cent. This reduction in the population level of the pest coincides with the increase of parasitism, as a comparison of columns 2 and 4 in Fig. 4 will show. It seems probable that the major portion, at least, of this reduction was due to the activities of the parasites.

The above discussion is based on figures for all of Niagara County. As a further indication of the effectiveness of the parasite, it may also be pointed out that where it has been longest established and consequently where parasitism is highest, the population level of the fruit moth is lowest. In the area about Lewiston, Youngstown, and Ransomville, the average infestation for 1932 was 9.14 per cent and the number of fruit moth larvae per acre was calculated as 5,407. As compared with the calculated number of 8,288 larvae per acre for the entire county (Table 2), this figure indicates a favorable trend. A population level as low as 5,407, while reflecting a situation not altogether to be desired by the fruit grower, is not, however, a serious situation. Whether the population level for the county as a whole will be reduced to or below this figure, future experience will determine. However, it now seems probable, that, unless other factors at present unknown intervene, the county as a whole may reasonably expect continued improvement with respect to the degree of infestation by the oriental fruit moth; at least to the extent of that shown in the Lewiston-Youngstown area.

It also seems reasonable to suppose that in the infested areas in Orleans, Monroe, and Wayne counties the history of the fruit moth will parallel that of Niagara County and that after the parasites become well established a reduction in the population level of the pest may be expected.

THE SPECIES CONCERNED

Macrocentrus ancylivorus is not the only parasitic factor operating on the fruit moth infestation, and therefore, is not wholly responsible for the reduction noted. However, it has taken a steadily larger toll of fruit moth larvae each year and ever since its establishment has been the largest single parasitic factor. Since this parasite increased each year, the decreases in total parasitism noted in 1929 and 1932 (Fig. 4) were due to variations in abundance of other parasites, chiefly *Cremastus minor* and *Glypta rufiscutellaris*. The remarkable increase in total parasitism in 1931 may be accounted for in large part by the appearance of *C. minor* in large numbers. This species did not appear in such great numbers in 1932, and consequently the total parasitism of the oriental fruit moth fell off even tho *M. ancylivorus* increased. A detailed consideration of the part played by each of 20 larval parasites in the reduction of fruit moth infestation in Niagara County is presented in Technical Bulletin No. 187 of this Station. It should be noted here, however, that 6 of these 20 species, namely, *M. ancylivorus, C. minor, C. forbesii, G. rufiscutellaris, Dioctes obliteratus,* and *Ascogaster carpocapsae* constituted over 99 per cent of all parasites emerging from twig collections made in Niagara County. It is also pointed out that *M. ancylivorus* alone constituted 56.07 per cent of all larval parasites in Niagara County.

To the above-mentioned list of 20 species of larval parasites there should now be added *M. laspeyresiae* Muesebeck, a larval parasite, and *Epiurus indagator* (Cresson), *Calliephialtes benefactor* Cushman, and *C. grapholithae* (Cresson), cocoon parasites. These four species, together with the 20 referred to above, and *Trichogramma minutum* and *Allocota thyridopterygis* make a total of 26 different species of parasites to be recorded as attacking the oriental fruit moth in western New York.

LABORATORY BREEDING METHODS

REARING HOST LARVAE

In any biological control project, one of the most important factors limiting the success of the undertaking is the possibility of rearing or obtaining the parasite in sufficient quantities. Unless the beneficial insect can be either reared or collected in large numbers success will not usually be obtained. Also, the possibility of rearing or obtaining a host insect in quantity is what usually limits the production of

the parasite. It is evident, therefore, that the availability in large numbers of a suitable host insect is of great importance in a program of biological control. In view of the above considerations, considerable time and effort have been devoted to the perfection of satisfactory technic for the rearing, both summer and winter, of suitable hosts for *M. ancylivorus* and other larval parasites of the oriental fruit moth. Two host insects have been used to a large extent in this work, namely the strawberry leaf-roller (*Ancylis comptana* Froël.) and the oriental fruit moth.

Obviously the production of the host insect is limited by the availability of suitable food material, and for this reason we have been restricted to the use of the oriental fruit moth thruout the winter when suitable food for the strawberry leaf-roller is not available in the field.

The oriental fruit moth is now reared in large numbers in the laboratory, and in maintaining a stock of this host thruout the winter several difficulties have been overcome. It might be well to record here the technic now in use after numerous experiments with various methods.

In obtaining eggs of the oriental fruit moth, an ordinary glass battery jar measuring 7 by 5 inches has been adopted as the most satisfactory and convenient type of oviposition cage. The top of this jar is closed with a piece of muslin held in place by rubber bands. From 100 to 200 oriental fruit moths are placed in the jar, a piece of moistened cotton batting covered with muslin to prevent the moths from becoming entangled is added, together with a few peach leaves, when available (Fig. 5). It was found that considerably more eggs were obtained if the cotton was moistened with a diluted mixture of either peach, apple, or quince

FIG. 5.—OVIPOSITION JAR FOR REARING ORIENTAL FRUIT MOTH.

fruit. By using one of these three materials oviposition was doubled. After setting up the jars, the procedure is as follows:

The jars are assembled in the morning and placed on their sides, with the bottoms toward the light, in a thermostatically controlled humidified incubator (Fig. 6) which maintains the temperature between 75° and 80° F and the humidity between 65 and 75 per

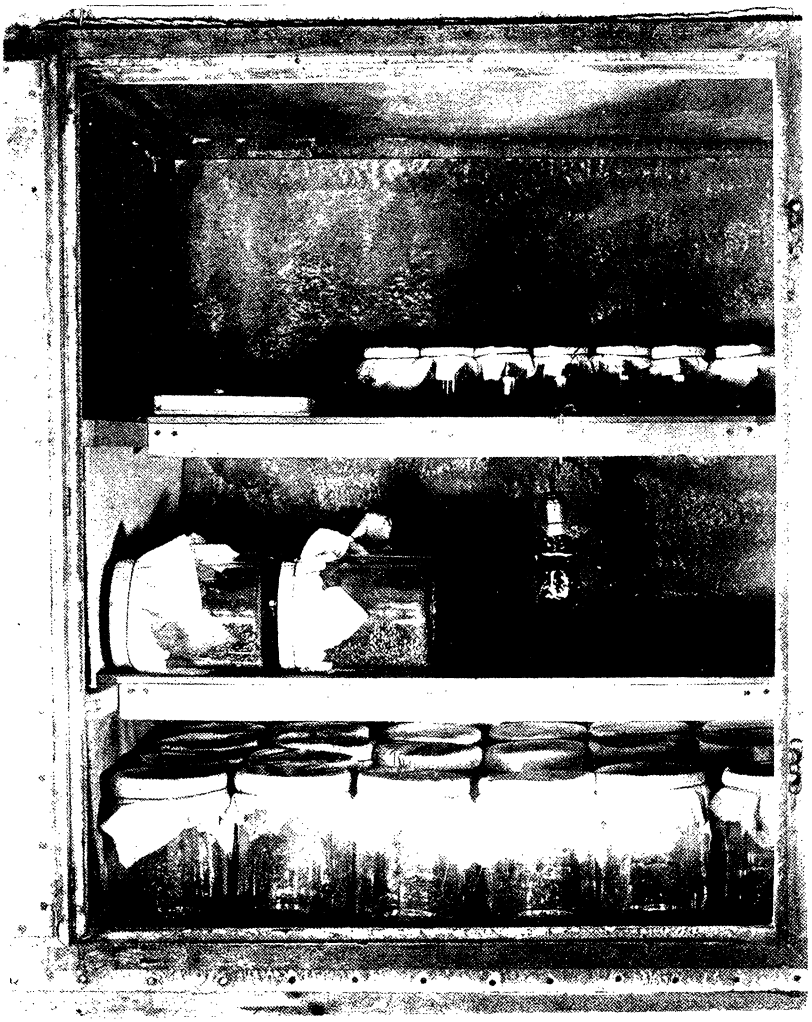

FIG. 6.—HUMIDIFIED INCUBATOR USED IN REARING WORK.

cent. The incubator is lighted by a 30-watt carbon filament bulb covered with red cellophane. The moths are thus left exposed to a soft red light. After numerous trials, the above procedure proved by far the best one tried in this laboratory for winter rearing. The eggs are laid all over the sides and bottoms of the jars and on the peach leaves, if present. The moths are changed to a fresh jar and new cotton pads are made up each morning.

The jars containing the eggs are returned to the incubator and left for 3 days, at which time the eggs are hatching. When the eggs begin to hatch the jars are filled with apples, or preferably quinces. The newly hatched larvae begin to bore into the fruit immediately, and in about 2 days the fruit is removed from the jars

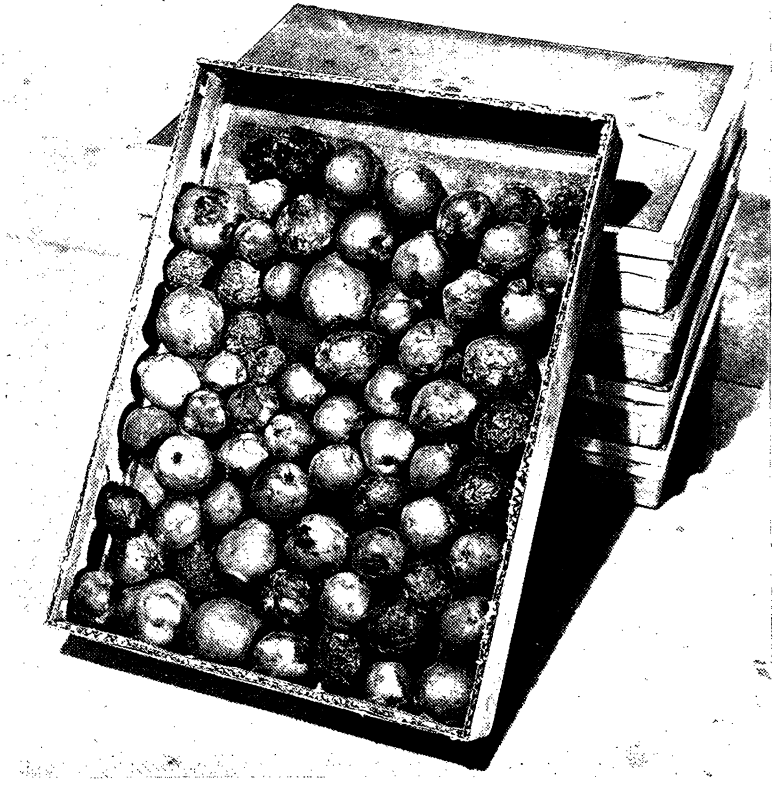

FIG. 7.—METAL TRAYS WITH SCREEN WIRE TOPS AND BOTTOMS USED IN REARING WORK.

and placed in metal trays with screen wire tops and bottoms. The trays are lined with strips of corrugated paper and sealed with adhesive tape (Fig. 7). The trays are then placed in another incubator (Fig. 8) which maintains the temperature at 80° F, but

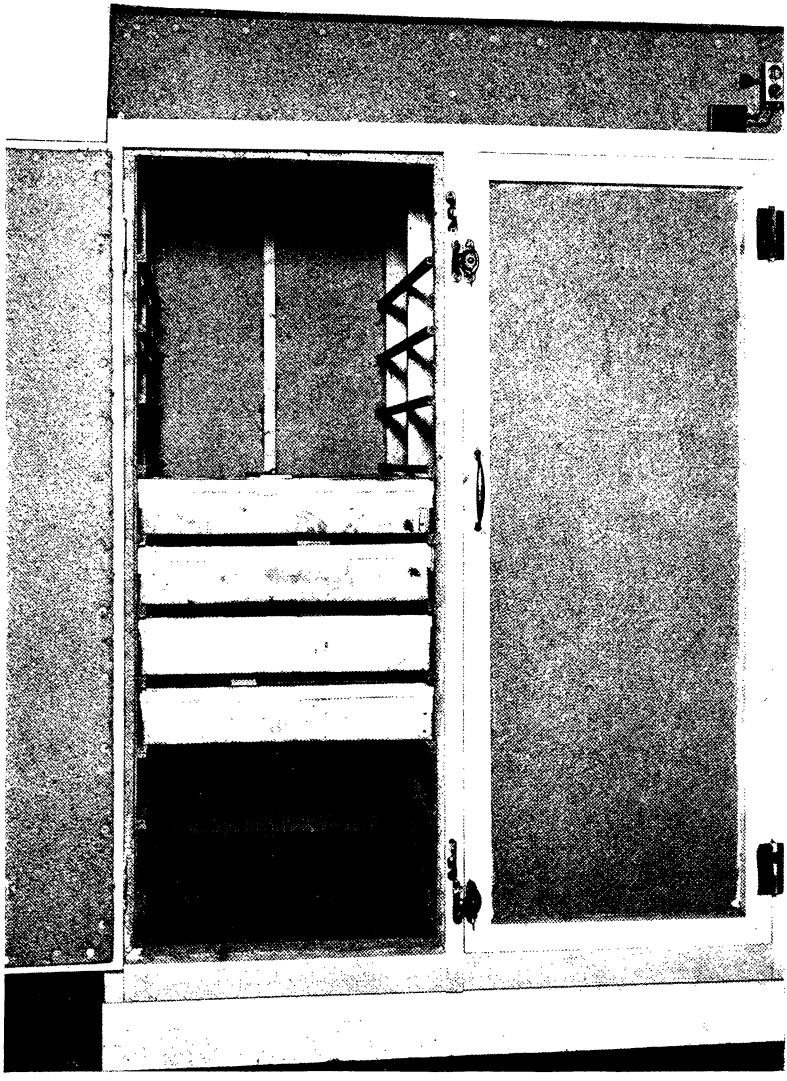

FIG. 8.—"DRY" INCUBATOR SHOWING ARRANGEMENT OF METAL TRAYS.

which does not raise the humidity above that of the room. This "dry" incubator is desirable since excessive moisture causes the fruit to rot very quickly. This is especially true with apples, and for that reason quinces have proved much more satisfactory. The trays are left in this incubator for 10 days to 2 weeks, at which time the larvae have completed feeding and spun their cocoons in the corrugated paper. The trays are then removed from the incubator and the corrugated paper containing the cocoons is removed and placed in an emergence room where the moths are allowed to emerge at will and are collected daily for the oviposition jars. By following the above procedures a stock of oriental fruit moths ample for the most ambitious parasite rearing project may be maintained thruout the winter.

The task of producing an adequate supply of fruit moths during the summer and fall months does not present quite the same difficulties as those encountered during the winter. The difference lies chiefly in the grade of fruit available for food. During the summer fresh fruit is abundant and little difficulty is experienced from loss of insects due to rotting fruit. Exactly the same procedure is followed as is used in the winter. Better results are secured by the use of the incubators than by carrying on the breeding in the insectary.

An entirely different method is followed with the strawberry leaf-roller during the summer. A wooden cage 5 feet wide, 3 feet high, and 24 feet long, covered with cheesecloth, is placed over two rows of strawberries. Into this cage are introduced 1,000 strawberry leaf-roller moths half of which are females. Under conditions existing at Geneva, this number of moths will lay enough eggs to infest practically every leaf in the cage. The eggs hatch and the larvae feed on the strawberry leaves. When pupation begins the folded leaves containing the pupae are easily collected. These pupae are collected in the leaves and the leaves tied in bunches and taken to an emergence room in the insectary. There they are arranged in metal trays with the stems projecting into water. The pupal stage is completed and the moths emerge in this room. The moths are then collected from the walls of the room and started on another life cycle in another cage.

REARING *MACROCENTRUS ANCYLIVORUS* ROHWER

The possibility of rearing or collecting the parasite in sufficient quantities is probably the limiting factor in a biological control project. Since the practice of collecting material containing the parasite and transferring it to New York could not be continued indefinitely, it was necessary that steps be taken looking toward the production of *M. ancylivorus* in the laboratory in numbers. One of the first steps in this direction is the production of quantities of a suitable host. Next it was necessary to determine how to obtain parasite eggs or how to have the host larvae parasitized, and then to determine the best method of handling the host larvae after they had been parasitized.

In order to secure parasitization of fruit moth larvae in the laboratory it is necessary to have the larvae confined in some medium from which they cannot readily escape when the female parasite attempts to oviposit in them; yet the medium must not be such that the parasites are unable to reach the larvae with their ovipositors. By far the most satisfactory method yet devised of obtaining parasitism of fruit moth larvae is to allow the larvae to bore into fresh peach twigs for a few hours and then to expose the twigs containing the larvae to the female parasites for a short time. The larvae bore into the twigs for a short distance and are thereby confined to the burrows in the twigs and cannot readily escape the ovipositing female parasite unless they have been allowed to burrow too far into the twigs. This method is, of course, limited during the winter by the absence of suitable twigs which may be collected from the field. However, this difficulty has been overcome to a large extent by the use of two expedients. First, before twigs in the field have hardened, several thousand twigs are collected, placed in cans of water, and stored in a refrigerated room maintained at 32° to 34° F. When the twigs in the field are no longer suitable for use, these twigs are removed from storage and used as needed. By this method it has been possible to utilize twigs for rearing the parasite for 2 months in the fall after twigs in the field become unusable. Second, small peach trees are transplanted to the greenhouse in the middle of winter, forced into early growth, and the twigs thereby obtained utilized for continued winter rearing of the parasite.

In the use of peach twigs for rearing the larval parasites during both winter and summer, the following procedure has been developed: The leaves are removed from the twigs with scissors, usually only

a short time before they are to be used, and the twigs clipped to the desired length by removing part of the bottom end. This gives added vigor, especially to twigs which have been stored for any length of time, by removing the lower portion which has become waterlogged. The twigs are then apportioned to battery jars containing oriental fruit moth eggs ready to hatch, so that one twig will be present for each 5 to 10 larvae. A shallow can containing water is placed in the bottom of the egg jar and the twigs placed in this can and arranged so that their tops come into contact with the upper sides of the jar (Fig. 9). The fruit moth larvae on hatching crawl

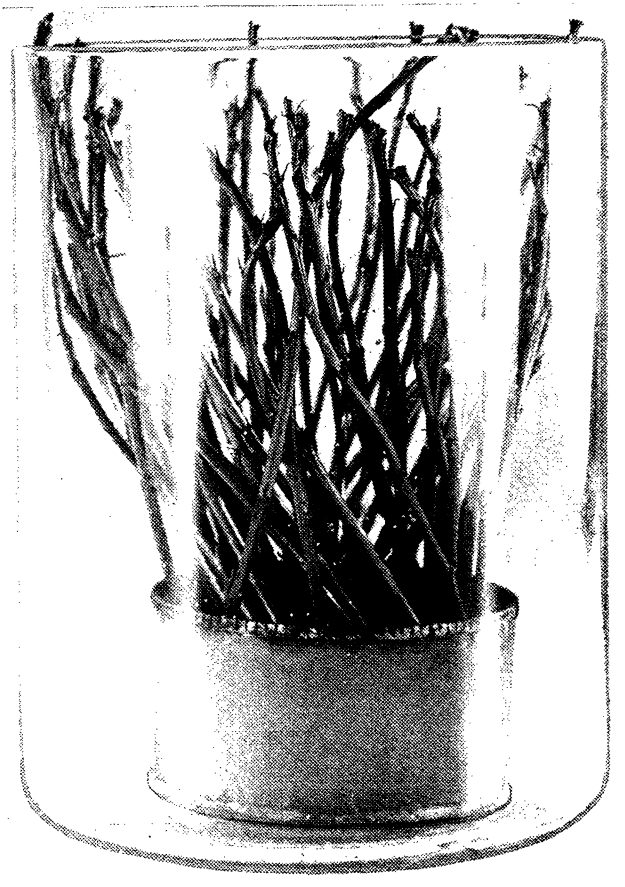

FIG. 9.—FRUIT MOTH OVIPOSITION JAR SHOWING ARRANGEMENT OF PEACH TWIGS.

upward on the sides of the jar and come into contact with the twigs. They then find a suitable place for entrance and begin to tunnel into the twigs.

The twigs are left in the jar over night and the following morning are exposed to the parasites. At that time the larvae have bored into the twigs for a sufficient distance so that they are not able to escape the ovipositing female parasite, and still they have not proceeded so far down the twig that the parasite is unable to reach them. The twigs containing the larvae are removed from the battery jar and apportioned to the parasite cages (Fig. 10) so that at least

FIG. 10.—PARASITE OVIPOSITION CAGE SHOWING FEMALES OVIPOSITING IN FRUIT MOTH LARVAE CONFINED IN PEACH TWIGS.

one active female parasite is present for each twig. The twigs are left in the parasite cage for about 1 hour and then removed. Fresh twigs may be added to the parasite cages immediately, but better results have been secured by allowing short rests for the parasites in between

periods of oviposition. Thus one period of oviposition is allowed in the early morning, another about the noon hour, and a third in the afternoon. During the period between oviposition the cages are covered so as to exclude most of the light, and the parasites eat, drink, and rest and do not chase around the cage as they would if the cages were well lighted.

After exposure to the parasites the twigs are removed, closely packed into a glass containing a small amount of water, and placed in an incubator for 2 to 3 days. The larvae grow rapidly in these twigs and by that time have practically consumed the twigs. The twigs are then removed and placed on fruit in a wood and cloth tray (Fig. 11). As the twigs begin to dry out, the larvae leave them and complete their feeding in the fruit.

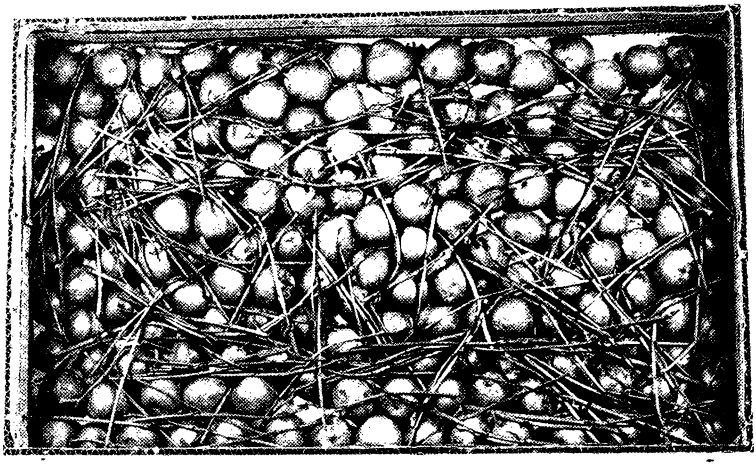

FIG. 11.—WOOD AND CLOTH TRAY FOR PARASITE REARING.

In winter rearing of the parasite, it is necessary to force these host larvae containing the parasite larvae into hibernation so that the parasites will not emerge until the following spring when they can be released in the field. This may be accomplished by holding the trays at a temperature of 32° to 40° F for 2 days, then at 70° to 80° F for 2 days, alternating thus until the fruit moth larvae have completed their feeding and spun their cocoons. The trays are then stored at outside temperatures until the following spring. Of

course, in summer rearing, the object is to secure the adult parasites as fast as possible for immediate release in the field, and therefore, the larvae are placed in the trays and allowed to feed continuously at summer temperatures.

When using the strawberry leaf-roller as a host in the summer, the procedure is relatively simple. About 1 week after introduction of the moths into the cage, as described above, a considerable number of eggs have been laid and have hatched. About 200 fertilized female parasites are then placed in the cage. These females search out the leaf-roller larvae in their webs in the folded leaves. They then puncture the larvae with their ovipositors and deposit eggs inside their bodies. The adult moths continue to lay eggs for about 3 weeks and the eggs continue to hatch, thereby furnishing a constant supply of new larvae in which the parasites continue to lay eggs. The 200 female parasites placed in the cage parasitize the larvae so successfully that it is necessary to maintain cages free from parasites to insure a supply of moths for future work. After being parasitized, the larvae continue feeding until mature and then construct their cocoons. At that time the parasite larvae have attained sufficient size to stop further activities of the leaf-roller larvae. The leaves containing the larvae are picked and placed in the insectary in the same manner as given above for handling leaf-roller material. Shortly after the parasite larva stops the activities of the leaf-roller larva, it emerges from the leaf-roller larva and consumes the remainder of its body. The parasite larva then spins its own cocoon inside of that of its host. Some few days thereafter the adult parasite emerges in the insectary and is collected for distribution to peach orchards.

SUMMARY

The oriental fruit moth is now well established in the entire commercial peach area of western New York, including Niagara, Orleans, Monroe, and Wayne counties.

The occurrence of the fruit moth in apples in appreciable numbers is noted. Quinces suffer severely from the ravages of the pest. The larval parasites which have apparently seen successful in reducing infestations in peach orchards have been unable to exert appreciable control in quinces because of the difficulty experienced by the female parasite in reaching with her ovipositor a fruit moth larva when it

is burrowing deep within a fruit. *Iscogaster carpocapsae,* which offered possibilities as a biological control factor in quince orchards because of its habit of laying its eggs within the eggs of the host, has proved ineffective.

The infestation in peaches in Niagara County reached a peak in 1929, and there has been a steady decline in injury since that time. It is probable that this reduction is due, in large measure, to the activities of parasites, particularly *Macrocentrus ancylivorus*. Yearly increases in parasitism in Niagara County by this species have been followed by appreciable reductions of injury.

One hundred and six colonies of *M. ancylivorus* have been distributed over the entire area of infestation in western New York. It now seems reasonable to suppose that after this parasite becomes well established in Orleans, Monroe, and Wayne counties a reduction in the population level of the fruit moth may result.

Satisfactory methods for rearing both hosts and parasites have been developed and are now in use.