Circular 140 March, 1940

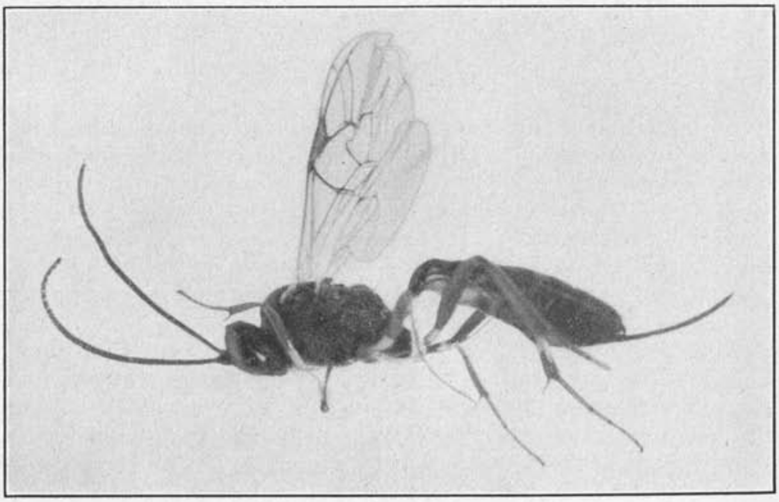
Connecticut Agricultural Experiment Station
New Haven

Oriental Fruit Moth Parasites

Philip Garman

THE PRESENT PARASITE SITUATION

1. In 1930, at the request of the Pomological Society, the Station began to rear and liberate Trichogramma egg parasites for control of the Oriental fruit moth in Connecticut. One of the main reasons for advocating this



A female larval parasite, *Dioctes molestae*

program was the fact that no satisfactory spray had been developed for this region. The Society raised $2,500.00 to help finance the original equipment and has since managed the sale of parasites to peach growers. This has brought the Station four or five hundred dollars per year. In 1937 and 1938 larval parasites also were distributed under this arrangement.

2. During the same time a program of research has been carried on in order to learn the effect of parasites and discover ways of making them more effective. This included:

a. The experimental release of 20 species[1], native and foreign. Nine of these species were bred in quantities in our laboratories.
b. Release of large numbers in small areas.
c. Recoveries of parasites from fruit moth larvae collected in orchards.
d. Efforts to improve the breeding technique, etc., etc.

The research program has been seriously handicapped by lack of funds and facilities, but we have learned many things. Some of these are:

a. It is evident that all parasite work needs to be placed on a sound experimental basis. All procedures **must be checked by experiment** in which as many factors as possible are known.
b. Continued liberations year after year maintain parasite stocks but do not increase them greatly. Whether or not larger liberations would be more effective is not known, but the work of Daniel in New York leads us to believe that they may be, at least for Macrocentrus larval parasites.
c. Large experimental liberations of egg parasites were ineffective in 1937 and 1938 because of unfavorable rainfall.
d. Reduction of fruit injury usually follows parasitism of fruit moth larvae in July exceeding 75 percent. There is some indication that egg parasitism above 50 percent reduces the amount of wormy fruit.
e. Prediction of the amount of infested fruit at harvest may be made with some accuracy from parasite recoveries in July, assuming that larval parasitism in that month below 75 percent is dangerous. However, the actual population of fruit moths is important in this connection.
f. Larval parasitism was at a low point in 1935 but has increased steadily since that time. It reached a high point in many orchards during 1939.
g. Liberation of foreign parasites has not produced immediate results, but at least three species have overwintered here and one appears to be increasing in abundance slowly.
h. The interval between serious fruit moth outbreaks since the work was begun is eight to nine years. Without continuous parasite liberations we believe this interval would have been shorter.

It is obvious that the problem is by no means as simple as claimed by some in 1930, or as might have been thought by our experience up to 1935. With the information and experience already in hand, and with reasonable facilities and funds, some of the most serious problems involved appear to be possible of solution.

[1] Supplied for the most part by the U. S. Bureau of Entomology from their imported stock.

Parasites for the Oriental Fruit Moth

PHILIP GARMAN[1]

Owing to confusion regarding the value of parasites for control of the Oriental fruit moth, it has been suggested that the results of nine years' experience be made available.

Our work with fruit moth parasites was begun in 1929 as a result of a demand from Connecticut peach growers. Laboratories were established in New Haven, stocks of parasites acquired and continuous breeding started. In 1932 quarters provided in Jenkins Laboratory afforded better facilities, and the small air-controlled laboratory there makes breeding possible throughout the year. With such equipment, parasites have been reared in considerable numbers, most of which have been sent out to growers with the hope that they might afford relief. In the meantime, limited experiments have been carried on covering the different phases of parasite breeding, release and parasitism in the orchard. Some of the results of this work are given in the following pages.

One of the main reasons for advocating the liberation or the maintenance of parasites in commercial peach orchards in Connecticut is that no satisfactory spray has been developed for this region. Serious difficulties exist in the use of artificial controls because of the three annual generations of the fruit moth, and the fact that the third generation is active so near harvest time. For these reasons it is very difficult to develop sprays which will not be injurious to the trees, will avoid objectionable residues and be economical enough for adoption by the grower. These difficulties are greater with peaches than almost any other fruit because peaches are harder to clean, the trees are more easily injured, and the value of the fruit today is rarely enough to warrant extensive programs such as are practiced for control of insects on apples.

Parasite control of the Oriental fruit moth is usually most effective when the parasitism is high and whenever the weather conditions are more favorable to parasites than to the moth. Obviously any condition reducing the number of moths without affecting the parasites will increase the percentage destroyed by parasites. For example, low sundown temperatures at the peak of third generation oviposition reduce the number of fruit moth eggs laid, Figure 1, and such a condition in the field would doubtless be favorable to certain parasites and predators. On the other hand, it is believed that many parasites are destroyed by heavy rainfall because they have less vitality than the fruit moth. In addition, they may be affected by their own enemies, known as secondary parasites, so that difficulties with the parasite method of fruit moth control are often as great and as serious in nature as with control by insecticides.

The day when unqualified recommendation of either method (sprays or parasites) can be made, awaits successful experimental and practical demonstrations over a number of years.

[1] A large part of the work on which this circular is based was done by W. T. Brigham, J. C. Schread and George R. Smith.

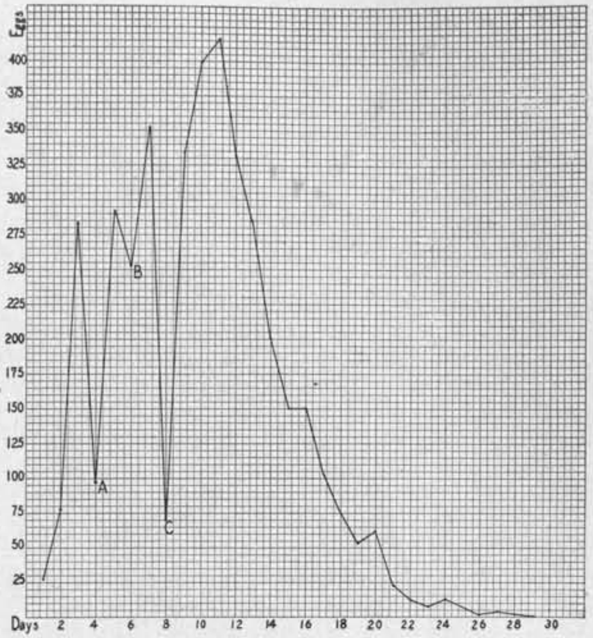


FIGURE 1. Chart showing the effects of lowering the temperature in a greenhouse where ovipositing fruit moths were kept. On days represented by A and C, the ventilators were opened enough to allow the temperature to drop below 65° F. in late afternoon. At B, the temperature dropped below 70° but not below 65°.

SPECIES OF PARASITES AVAILABLE, THEIR SOURCE, AND WHERE LIBERATED

The Connecticut Agricultural Experiment Station has made use of nine different species of introduced parasites, all of which have been liberated in most of the peach-growing areas. They are as follows:

1. *Ascogaster 4-dentatus*	larval parasite from Europe
2. *Bassus diversus*	larval parasite from Japan (Fig. 2D)
3. *Dioctes molestae*	larval parasite from Korea (Fig. 2C)
4. *Macrocentrus ancylivorus*	larval parasite from New Jersey (Fig. 2B)
5. *Orgilus longiceps*	larval parasite from Japan
6. *Phaeogenes haeussleri*	pupal parasite from Japan
7. *Perisierola angulata*	pupal parasite from Australia
8. *Trichogramma pretiosa*	egg parasite from Connecticut
9. *Trichogramma minutum*	egg parasite from southern United States

A list of the native parasites reared from the Oriental fruit moth in Connecticut, together with a list of the more important primary parasites and secondary parasites affecting the primaries, is given below:

Primary Parasites

1. *Apanteles clavatus* Prov.
2. *Apanteles epinotiae* Vier.
3. *Apanteles harti* Vier.
4. *Ascogaster carpocapsae* Vier.
5. *Cremastus carpocapsae* Cush.
6. *Cremastus epagoges* Cush.
7. *Cremastus forbesii* Weed
8. *Cremastus longiventris* Cush.
9. *Cremastus minor* Cush.
10. *Cryptus vinctus* Say
11. *Dioctes obliteratus* Cresson
12. *Eubadizon pleuralis* Cresson
13. *Glypta rufiscutellaris* Cresson (Fig. 2A)
14. *Glypta vulgaris* Cresson
15. *Isadelphus smithii* Packard
16. *Itoplectis conquisitor* Say
17. *Lixophaga plumbea* Aldr.
18. *Lixophaga variabilis* Coq.
19. *Macrocentrus ancylivorus* Roh.
20. *Macrocentrus delicatus* Cresson
21. *Macrocentrus instabilis* Mues.
22. *Meteorus trachynotus* Vier.
23. *Phanerotoma tibialis* Hald.
24. *Pristomerus ocellatus* Cush.
25. *Sagaritis dubitata* Cresson
26. *Trichogramma minutum* Riley
27. *Trichogramma pretiosa* Riley

More Important Primary Parasites

1. *Macrocentrus ancylivorus*
2. *Trichogramma pretiosa*
3. *Glypta rufiscutellaris*
4. *Eubadizon pleuralis*
5. *Isadelphus smithii* Packard

Secondary Parasites

1. *Dibrachys boucheanus* Ratz.
2. *Eurytoma* sp.
3. *Gelis* sp.
4. *Hemiteles tenellus* Say
5. *Perilampus* sp.
6. *Eupelmus* sp.

NOTE. List contains species collected through 1938 and previous to that year.

Statistics of the parasites supplied to Connecticut growers from the New Haven laboratory are given in Table 1.

TABLE 1. PARASITES SUPPLIED TO CONNECTICUT GROWERS

Year	Trichogramma	Macrocentrus	Dioctes	Bassus	Perisierola	Phaeogenes	Orgilus	Ascogaster
1930	6,540,000	11,600						
1931	11,337,000	10,000						
1932	18,000,000	31,836						
1933	28,300,100	4,656						991
1934	9,253,000	30,500			5,156			
1935	8,590,000	6,462		5,199	7,750			
1936	11,000,000	5,200	3,800	16,100	12,000			
1937	7,010,000	20,208	6,137	27,380		7,673	391	
1938	5,300,000	4,670	6,974	835		3,911	6,900	
	105,330,100	125,132	16,911	49,514	24,906	11,584	7,291	991

In addition to those listed, the U. S. Bureau of Entomology has liberated 11 other species in small numbers. These are *Macrocentrus thoracicus*,

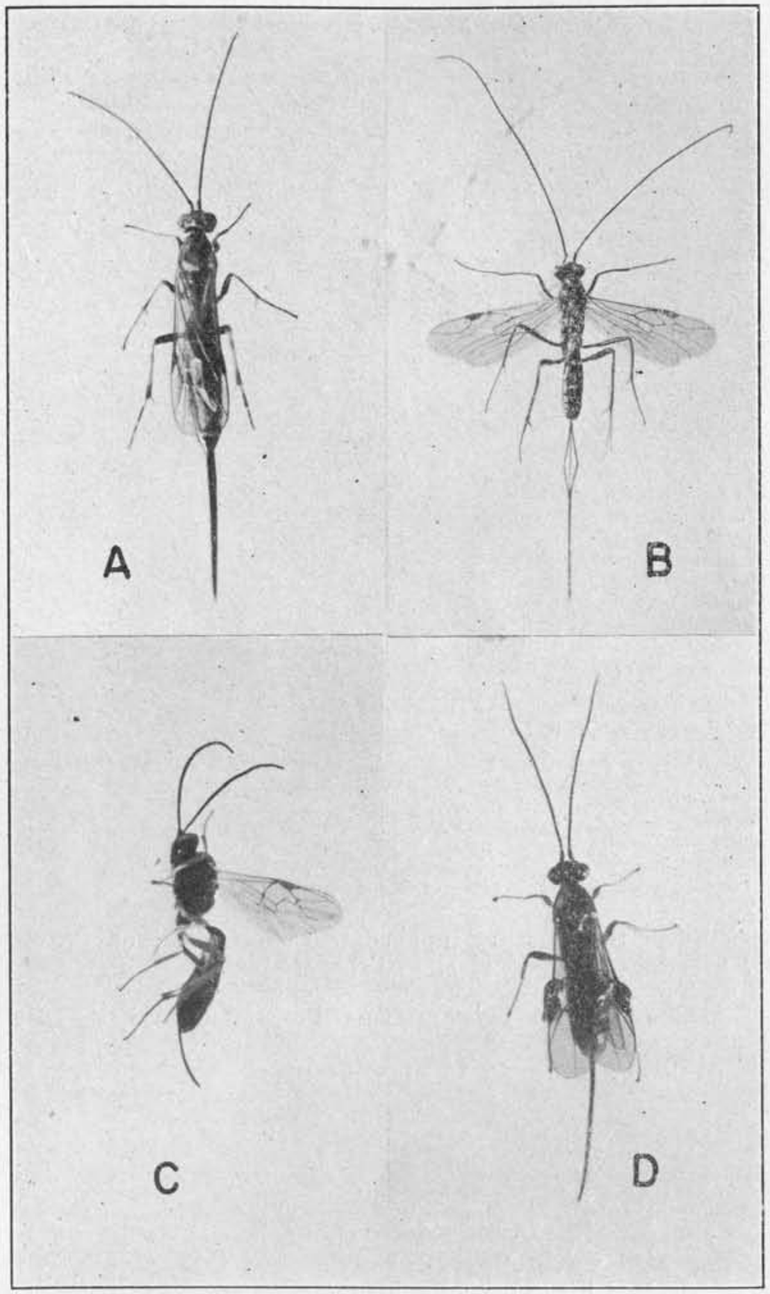


FIGURE 2. Female larval parasites of the Oriental fruit moth. A. *Glypta rufiscutellaris*, an important native species. B. *Macrocentrus ancylivorus*, a species abundant in New Jersey, Delaware and Maryland and brought to Connecticut in considerable numbers. C. *Dioctes molestae*, obtained in Korea by the U. S. Bureau of Entomology. Bred and released throughout Connecticut. It fails to survive in most orchards more than one or two years. D. *Bassus diversus*, a species obtained in Japan by the U. S. Bureau of Entomology. Appears to have survived in some orchards for three years.

Apanteles sp., *Tachinidae* sp., *Cremastus* sp., *Pristomerus vulnerator*, *Bassus conspicuous*, *Eubadizon extensor*, *Elodia* sp., *Phanerotoma laspeyresiae*, *Trichogramma euproctidis* and *Trichogramma evanescens*. Altogether a total of 20 parasite species has been supplied by the Federal Bureau.

Of the introduced forms, the most important at the present time appear to be *Dioctes molestae* and *Bassus diversus* from Korea and Japan, respectively. Whether or not any of the other parasites will ever become important factors in fruit moth control is unknown, although it is possible that some of them will be abundant in the future and much more important than they seem to be at present.

Twenty-six species of native parasites have been recovered or bred from the Oriental fruit moth, and at least four species have some influence in reducing the population. These are *Macrocentrus ancylivorus*, *Trichogramma pretiosa*, *Glypta rufiscutellaris* (Figure 2A), and *Eubadizon pleuralis*. The first two of these have been bred in large numbers and liberated in many orchards.

Distribution of various parasites throughout Connecticut is shown in Table 1 and in Figures 5, 6, 7, 8, 9 and 10.

INTRODUCTION FROM ABROAD

Species introduced from abroad are desirable because they frequently have different habits from the native species and may survive weather or other conditions seriously affecting native forms. Theoretically the greater the number of successful species established in an orchard, the greater the total parasitism will be; or, the greater the chances that some of them will find and kill the host—in this case the Oriental fruit moth.

The primary phase of such a project consists of introducing as many different forms as possible from regions similar to ours and observing which of them, if any, become abundant enough to be of benefit. The second phase of such a project is concerned with introduction of the successful species into every possible location where they have a chance to survive.

We believe that introduction of foreign parasites is worth while on these grounds. At the present time, all species available have been distributed throughout the State, and the second phase awaits successful development of the species concerned in numbers sufficient to warrant further distribution.

MAINTENANCE OF SPECIES ALREADY PRESENT

In Connecticut, parasite species such as Macrocentrus are apparently on the northern limit of their natural range. Hence it is reasonable to expect that they will decrease, or even disappear, during unfavorable periods, only to reappear when conditions are more suitable. In the case of certain insects with similar range, migration then occurs from points farther south, so that it seems desirable to keep stocks of parasites available for introduction whenever they have been present and subsequently disappeared. This is essentially the situation in regard to *Macrocentrus ancylivorus*, although there are some areas in the State where the species has apparently not become abundant even with repeated introductions.

THEORIES AND OBSERVATIONS ON THE CAUSES OF FRUIT MOTH AND PARASITE FLUCTUATIONS

Natural Factors Affecting Abundance of Parasites

Some of the difficulties in the use of parasites for control of the Oriental fruit moth have already been mentioned. Unfavorable factors are known or thought to be the following: Heavy rainfall and high sundown temperatures during the growing season; scarcity of secondary hosts; open winters and falls, and destruction of peaches by cold weather. Conversely, favorable conditions consist of cool falls, light rainfall during the summer, and sundown temperatures below 65 degrees during August.

Taking the various factors in order, it has been shown that heavy rainfall promotes abundant twig growth of the peach tree and that the number of infested shoots per tree is directly correlated with this condition. As has already been seen, Figure 1, sundown temperatures above 70 degrees F. favor egg laying on the part of the fruit moths so that they are likely to gain considerably over their parasites under such conditions. In addition, rainy periods destroy egg parasites, removing one of the natural checks on their development.

Scarcity of secondary host insects is probably a factor affecting such parasites as Macrocentrus. It is well known that Macrocentrus develops on the strawberry leaf roller larva, an insect quite abundant in New Jersey and Delaware. In consequence, Macrocentrus abundance there is nearly always greater than in Connecticut where such secondary hosts are relatively scarce.

Some important larval parasites pass the winter in an early stage of development. Open winters and falls allow them to develop faster than the host which they parasitize, hence there is a tendency to be more easily killed by cold because they are too far advanced; also they may emerge too early in spring, if not killed during the winter. There will be few host larvae on which the female can lay eggs at that time; hence the parasites perish, or the normal rate of increase will not be attained.

The destruction of peaches by cold, resulting in a no-crop year, allows little food for the third generation of the fruit moth on which larval parasites are dependent. There follows a marked reduction in the number of parasites passing the winter, so that at the beginning of the following year there will be a light infestation of the fruit moth which has few or no parasites. The initial moth infestation frequently increases rapidly, being unhampered by various parasites, so that severe fruit damage is often experienced the year following destruction of the crop by cold weather. Such a condition is reported from the Midwest, but the no-crop years of 1933 and 1934 were not followed immediately by abnormal increases in the abundance of the Oriental fruit moth in Connecticut.

Theories of Parasite and Host Abundance

Laying aside the consideration of favorable or unfavorable weather conditions that occur from year to year, the commonly accepted theory of increase of host and parasite is that of Volterra. This investigator states that parasite increase follows the rise of host abundance and reaches its peak shortly after the host has started to decline. After the parasite

reaches a peak of abundance, the host population may decline rather rapidly, followed by a similar decline on the part of the parasite. This is illustrated graphically in Figure 4.

Another theory (Smith) concerns the so-called searching ability of the parasite or predator. Briefly stated it says that the effectiveness of any given parasite depends on the ability and energy with which it seeks its food. This is one of the more important factors influencing the abundance of any one species and, for the most part, we have selected for distribution in Connecticut species that are energetic in seeking the fruit moth.

Alternate hosts likewise play an important part. If a parasite has a number of alternate hosts on which it feeds, given the same ambition or ability to seek the host, it will be far easier for it to find suitable food where the alternate hosts are plentiful than where they are not. Survival and multiplication are correspondingly more rapid for such a parasite, especially if the alternate is available during periods when the primary hosts are scarce.

COMPARATIVE VIGOR OF THE ORIENTAL FRUIT MOTH AND ITS PARASITES

Assuming then that fruit moth parasites have reached an equilibrium, that all introduced species have become acclimated, that they have increased to a figure commensurate with their searching ability and that they have located available secondary hosts on which they can survive, the weather may still intervene and the host reach outbreak proportions unless parasites are found that have equal vitality. In this regard the Oriental fruit moth may still be considered more vigorous than its known natural enemies. With the successful establishment of parasites from abroad, however, such outbreaks as occurred in 1929, 1937 and 1938 should be of less and less frequency and the successful maintenance of Macrocentrus should be of considerable help in this regard.

EFFECT OF MASS LIBERATIONS

A study of insect populations such as the Oriental fruit moth in the field indicates that their numbers are not so great but that carefully planned parasite liberations in sufficient quantities would theoretically bring about control. Likewise, a moderate degree of parasitism which would ordinarily not be effective against the fruit moth might be increased by liberations to a point where considerable benefit would result. Either program may be upset by unfavorable weather.

The benefit to be derived from liberations of large numbers of parasites such as Trichogramma is problematical, for, if a native species such as this has not increased of its own accord to an effective stage, it indicates that natural resistance of various environmental factors is great enough to dampen the effect of any number of artificial releases. We have been able, however, to increase parasitism by Macrocentrus and Trichogramma through artificial liberations, though not enough to be of immediate benefit in most cases. Here is a need for continued investigation, and development of increased production to that end. Liberations of Trichogramma in 1938 were a failure, as indicated in Table 2. It appears necessary to obtain an egg parasitism of 50 percent or better, or a July larval parasitism above 75 percent, before much reduction in infested fruit is noticed. (See Tables 7 and 8.) Thus it will be seen that an increase of egg parasitism from 15 to 25 percent, or an increase of larval parasitism from 25 to 40 percent, would not be enough to provide the desired protection. To increase the degree of parasitism to the effective point in such years as 1938 appears impossible with the methods employed.

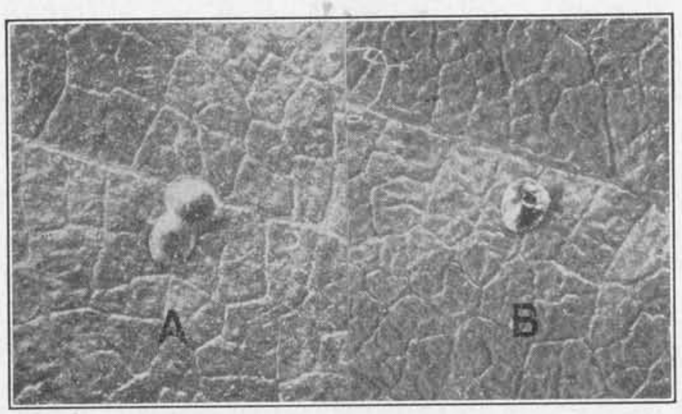


FIGURE 3. Oriental fruit moth eggs showing effect of parasitism by Trichogramma. A. Two normal eggs. B. Egg from which parasite has emerged through the circular hole.

TABLE 2. EFFECT OF TRICHOGRAMMA LIBERATIONS ON ORIENTAL FRUIT MOTH INFESTATIONS, 1938

Orchard and location	Elbertas percent wormy	Percentage of eggs parasitized by Trichogramma	Number liberated per acre	Dates of liberation and spacing
A Cheshire	63.4	9.4	500,000	50,000 each week June 7 to Aug. 9 4,000 every 4th tree
B Guilford	44.8	10.6	200,000	66,000 monthly by fruit moth generations 4,000 every 4th tree
C Milford	42.3	29.3	250,000	83,000 monthly by fruit moth generations 4,000 every 2nd tree
Check (Av. of several orchards)	—	21.0	0	No liberations

About all that can be expected from limited parasite liberations, then, is maintenance of the species with possibly enough increase in favorable years to reduce the amount of wormy fruit. Even this, however, is worth continuous effort.

The following tables show the degree of parasitism that may sometimes be obtained from successful liberations of Trichogramma and the amount of parasitism that is necessary before any reduction in fruit injury is apparent.

TABLE 3. PARASITISM BY TRICHOGRAMMA IN AN ORCHARD RELATIVELY FREE OF LARVAL PARASITES. COUNTS IN TWO DIFFERENT YEARS

Orchard	Average percentage Trich. parasitism	Percent infested fruit at harvest
Conn. State College, Storrs	15	80
	50	53

TABLE 4. PARASITISM BEFORE AND AFTER TRICHOGRAMMA LIBERATIONS

Dates of liberation	Percent parasitism before	Percent parasitism after
August 29	0	52
August 6	5	58
June 6	40	53

It would appear from Table 4 that liberations are more successful when the natural parasitism is low and are more effective in late summer than in June.

EFFECT OF CONTINUED LIBERATIONS OF MACROCENTRUS AND TRICHOGRAMMA

So far we have been able to raise the level of Macrocentrus parasitism only slightly (Table 5). Thus, from the figures obtained in 1937, it will be seen that the total larval parasitism in seven orchards where no parasites were released was 4.7 percent, whereas the total parasitism in orchards where Macrocentrus had been released during the preceding years was only 11.7 percent. The method here employed was that of liberating small colonies of 200 to 500 per orchard.

Liberations of Trichogramma over a period of years increased the parasitism from 19 to 35 percent in 1937. The method in this case was to place approximately 40,000 parasitized grain moth eggs per acre of peach orchard. As already explained, much larger liberations of Trichogramma in 1938 were of no avail. Table 2.

TABLE 5. MACROCENTRUS RECOVERIES, 1937

Orchard and location	Date	Productive tips collected[1]	Macrocentrus recovered	Percent parasitized by Macrocentrus
NO LIBERATIONS DURING THE LAST TWO YEARS				
Shepard—Danbury	June 11	38	0	
Spicer—Deep River	June 13	38	1	
Conyers—Greenwich	June 15	68	0	
Shiffrin—Milford	June 23	20	0	
Shiffrin—Milford	July 10	19	0	
Shiffrin—Milford	July 21	23	0	
College—Storrs	July 14	54	0	
College—Storrs	Aug. 19-25	45	11	
Expt. Sta.—Mt. Carmel	July 16	29	1	
Coolac—Branford	July 24	22	4	
		356	17	4.7

[1] Either moths or parasites reared from them.

Orchard and location	Date	Productive tips collected[1]	Macrocentrus recovered	Percent parasitized by Macrocentrus
MACROCENTRUS LIBERATIONS DURING 1936 AND 1937				
Swanson—Mill Plain	June 11	17	0	
Whittle—Mystic	June 13	24	0	
Sonozzaro—North Haven	July 17	9	4	
Root—Farmington	June 12	43	5	
Lyman—Middlefield	June 19	4	0	
Lyman—Middlefield	July 17	7	0	
Lyman—Middlefield	July 24	34	5	
Bishop—Cheshire	July 7	7	1	
Bishop—Cheshire	July 21	5	2	
Rogers—Southington	July 21, 24	29	4	
		179	21	11.7

[1] Either moths or parasites reared from them.

At the present time it is not known whether larger liberations of larval parasites would be more effective in raising the average level of parasitism, but work of Daniel in New York indicated that a liberation of 12,000 Macrocentrus in a 72-acre peach orchard gave favorable results the first season. Our highest yearly production totalled 62,000 larval parasites which (if all were Macrocentrus) would be about enough for 160 acres at the rate mentioned. The total acreage in peaches in Connecticut is, of course, much greater, so that the yearly production is inadequate to provide the protection reported by Daniel. It also seems probable that unfavorable seasons would require many more than the effective number reported by him.

TABLE 6. TREND OF LARVAL PARASITISM DURING THE PERIOD FROM 1936 TO 1938 INCLUSIVE

County	1936	1937	1938
Hartford	5.0	21.4	24
Middlesex	5.8	8.8	47
New Haven	12.9	27.3	52

TREND OF PARASITE ABUNDANCE IN CONNECTICUT

The chart in Figure 4 gives the trend of fruit moth and parasite abundance during the last ten years. Collections of infested twigs during the years from 1936 to 1938 inclusive showed that larval parasitism increased steadily in spite of more or less unfavorable weather during that time. The dotted portion of the curves indicates what may reasonably be expected during the next two years.

It will be seen from Table 6 that the parasitism in Hartford County has not advanced as rapidly as that of New Haven County though an increase is evident. If we figure that a parasitism during July of 75 percent or better is necessary for reasonable moth control, an increase similar to that occurring in 1937 and 1938 would bring parasitism above 75 per-

cent for New Haven and Middlesex counties. Doubling the parasitism will not make it high enough for Hartford County, but continuation of the general trend would bring it by 1940 to a high point without further introductions. Parasitism actually did increase to an effective point in 1939 for Hartford as well as New Haven and Middlesex counties.

During the period covered in Table 6, Trichogramma parasitism increased little or none at all, which was probably due to the adverse effects of heavy July or August rainfall during 1937 and 1938.

PREDICTION OF OUTBREAKS

It has been possible to make limited predictions regarding the possibility of heavy fruit infestations in Connecticut by studying parasite recovery collections during July. Thus, as will be seen in Tables 7 and 8, a high larval parasitism during July resulted in a low infestation at harvest. During the season of 1937 and 1938 we were able to predict moth damage

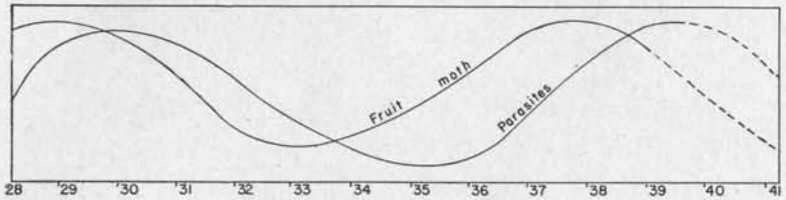


FIGURE 4. General status of the Oriental fruit moth between 1928 and 1939. Dashes indicate what may reasonably be expected to happen up to 1942. Degree of infestation and parasitism is purely arbitrary.

with considerable accuracy. This situation was intensified, as was pointed out, by heat and the heavy rainfall during July or August which apparently destroyed Trichogramma parasitism.

TABLE 7. COMPARISON OF PARASITISM BY MACROCENTRUS AND DEGREE OF ELBERTA INFESTATION THE SAME SEASON

Orchard and location	Year	Parasitism of second brood larvae[1]	Percent infested Elbertas	Notes
Experiment Station Farm				
Mount Carmel	1933	93	7	Average of drops and picked
Bishop Farms				
Cheshire	1932	89	10	Average of drops and picked
Pero Brothers	1932	75	8	Count of drops: picked fruit less
Manchester	1933	85	11	Count of drops: picked fruit less
L. C. Root & Son				
Farmington	1933	85	16	Count of drops: picked fruit less
Connecticut State	1931	0	80	Average of picked and drops
College	1932	0	50	Average of picked and drops
Storrs	1933	2[2]	72	Average of picked and drops

[1] Mid-July.
[2] Total larval parasitism (Glypta and others) 17 percent. Macrocentrus introduced in August, 1932. First recovery August, 1933.

TABLE 8. EFFECT OF JULY LARVAL PARASITISM ON AMOUNT OF INFESTED FRUIT—1937

Orchard	Larval parasitism in July	Percent of fruit infested	average
1	0	40.5	32.1
2	3.4	27.0	
3	26.4	16.9	23.2
4	37.5	26.4	
5	52.9	26.4	
6	60.0	16.0	10.5
7	85.7	5.0	

Despite the figures given in Tables 7 and 8, occasional orchards have been found from time to time which indicate that high July parasitism of the fruit moth (above 75 percent) does not always produce a low infestation at harvest. It appears from studies in 1939 that the actual moth population may play a part here. Consequently all parasitism was taken into account in that year and the percentages applied to the population, which was roughly estimated in some cases. The figures are given in Table 9. They indicate an increased infestation of fruit parallel to an increased survival of fruit moths as parasitism decreases. It stands to reason also that in cases of very low moth populations, which occur in some localities, clean fruit will be produced whether parasites are present or not.

It seems probable that egg parasites increase under the same conditions that cause the larval population to rise. Hence the figures obtained in Tables 7 and 8 indicate the general trend of egg as well as larval parasitism but do not take into account the population of fruit moths or the causes of its variation. The actual cause of differences in populations in different orchards during 1939 is not altogether clear, though in many cases a low July population was preceded by a high larval parasitism in June. It is our general impression that dry weather in July reduced the fruit moth abundance considerably over 1938, but it did not do so in every orchard, since harvest counts indicated nearly as high percentages as in 1938. The whole problem is exceedingly complex, though since 1936 we have predicted with considerable accuracy what the grower might expect in the way of fruit moth infestations following studies of the parasitism during July.

TABLE 9. CONDENSED RESULTS OF STUDIES ON THE ORIENTAL FRUIT MOTH, 1939

Orchard	Fruit moth population estimates[1]	July survival of fruit moth[2]	Elberta infestation at harvest, %
Bishop 1939	49	2.4	6 ± 2
Rogers	30	2.7	1 ± 1
Bussa	36	4.5	11.2
Peters	18	6.0	8.0
Andrews	89	11.7	22.5
Hanford	200 (est)	23.7	30.3
Platt	125	26	31.9
Hurlbutt	100	67.5	25.2
Musante	150	83.9	42.4
Bishop 1938	200 (est)	117	63.4

[1] Population estimates are counts of eggs on an hourly basis supplemented by consideration of twig infestations in each orchard. The figures marked (est) are based largely on the impressions of the collectors in those orchards and comparison with orchards where more careful counts were made.
[2] Based on reduction of orchard population by parasites. Obtained by subtracting from the population estimates in column 1, the percentage known to have been destroyed by parasites determined by laboratory rearings.

BREEDING OF PARASITES

It is possible to produce Trichogramma egg parasites in millions, our maximum in one year being 28 millions. With our equipment it is therefore possible to rear these parasites in quantities 600 to 700 times as great as we can produce larval parasites.

The main limiting factors in parasite breeding are quantity and quality of food, amount of labor and equipment—particularly storage facilities—and presence of predators in the breeding rooms. It is necessary to provide cold storage suitable for fruit and also for insects, which require different conditions. A small mite, *Pediculoides ventricosus*, destroyed large numbers of larval parasites in 1938 and ruined some of our grain moth stocks used for Trichogramma work in 1937. Equipment that can be sterilized, and separate units or rooms are necessary so that the work may be continued without interruption.

It will also be seen that breeding a single insect in quantities may be difficult under laboratory conditions. The necessity of breeding two simultaneously, so that the right stage of one is always available in quantities for presentation to the parasite, which must also be at a certain stage of development, is a much more complicated process. As a hypothetical illustration, it would be similar to breeding large numbers of ferrets which would only reproduce after a certain age and then only when fed on rats. The rats, in turn, would likewise have to be a certain age but different from that of the ferrets. However, the problem is not too difficult and may be solved in the future as more and more is learned about breeding methods.

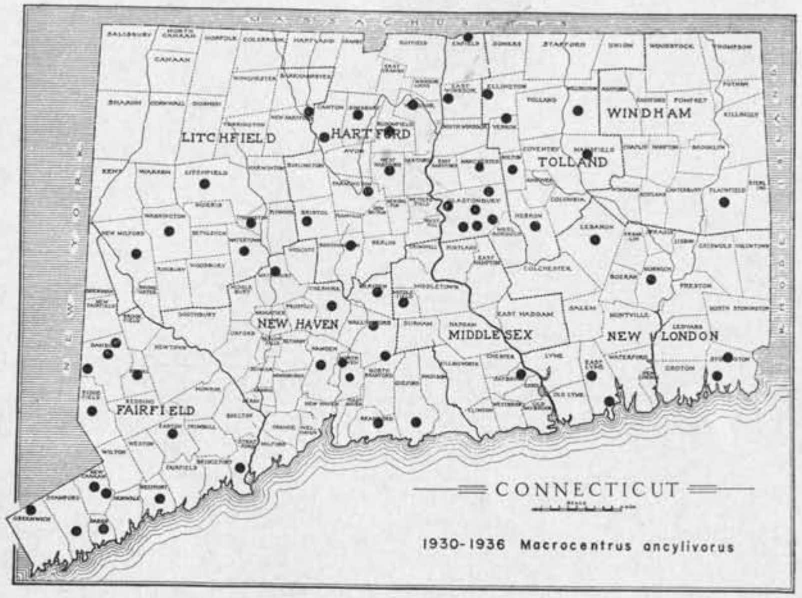


FIGURE 5. Colonization of Macrocentrus between 1930 and 1936.

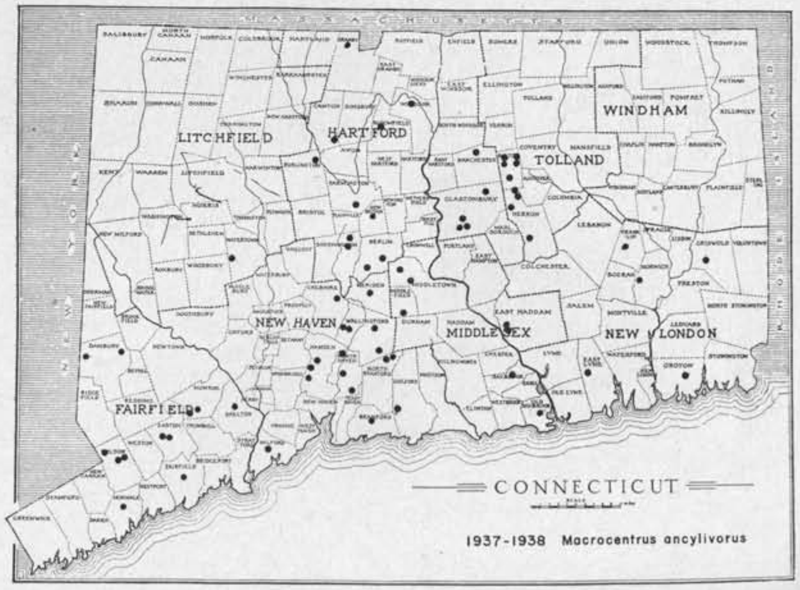


FIGURE 6. Colonization of Macrocentrus during 1937 and 1938.

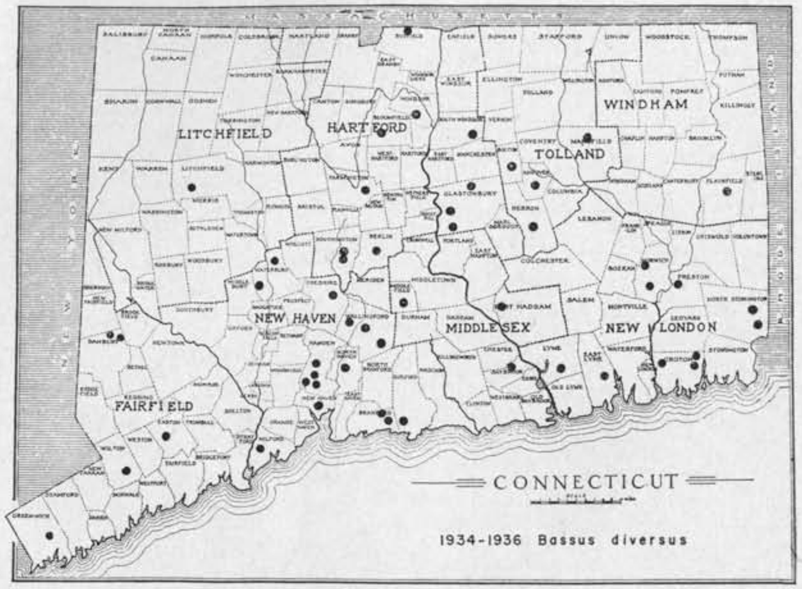


FIGURE 7. Colonization of *Bassus diversus* from 1934 to 1936.

FIGURE 8. Colonization of *Bassus diversus* during 1937 and 1938.

FIGURE 9. Colonization of *Dioctes molestae* from 1933 to 1938.

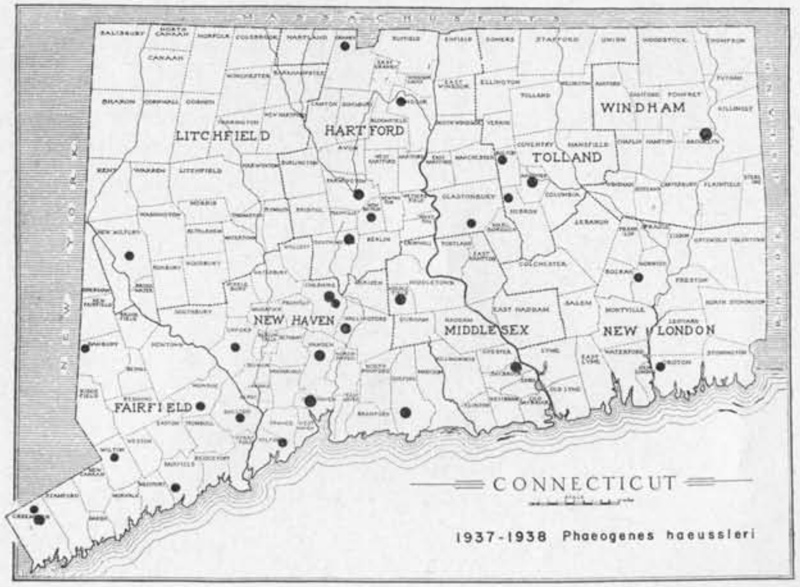


FIGURE 10. Colonization of *Phaeogenes haeussleri* during 1937 and 1938.

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