# T H E S I S

on

# The Commercial Propogation and Biological Studies of Two Parasites of the Codling Moth.

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by

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# TABLE OF CONTENTS.

# LIST OF ILLUSTRATIONS.

# COMMERCIAL PROPOGATION AND BIOLOGICAL STUDIES OF TWO PARASITES OF THE CODLING MOTH.

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## STATEMENT OF THE PROBLEM.

Investigations of rearing methods for commercial propogation of two egg parasites (Trichogramma minutum Riley and Ascogaster carpocapsae (Viereck)) of the codling moth, Carpocapsa pomonella L., together with liberation experiments and observation on their life history and habits were undertaken to determine whether the insects could be raised and liberated in large enough numbers to become commercial factors in the reduction of one of the worst apple pests the Oregon grower has to combat. Experiments were conducted by the writer at the Oregon Experiment Station, Corvallis; the Hood River Experiment Station, Hood River, Ore.; and at the Dominion Entomological Laboratory, Vernon, B. C., Canada. The work covered a period of 20 months, starting in the summer of 1927 at Vernon, B. C.

## I TRICHOGRAMMA MINUTUM Riley.

### INTRODUCTORY REMARKS.

Anyone at all familiar with the insect complex appreciates the importance of insect enemies of insects. Dr. L. O. Howard, former chief of the Bureau of Entomology, says, "So important does their work appear to me that I am inclined to rank it the main factor in the preservation of the so-called 'balance of nature.' Surely it is one which demands our most careful attention."

Man is constantly being forced to increase the sources of his food supply in order to meet the ever-growing human population. He thus opens up enormous avenues of increase for hosts of insect pests. This in turn allows the development of countless numbers of insect enemies of insects -- parasites and predators -- to take place at a corresponding rapid rate. Such development is as it should be, and the injurious insects are reduced accordingly. Natural reduction in this manner is a slow process,however, and man, being impatient, has tried to speed up the procedure.

Man cannot wait for the relatively slow adaptation of native parasites to new hosts; so beginning with the start of the present century, he has hastened the process by introduction of parasitic and predatory forms already adapted to the insect pest accidently imported.

Within the past five years entomologists engaged in biological control of insects were brought face to face with a new development -- a development within a development one might say -- in the control of insects by parasites. Briefly stated -- the raising of an indigenous parasite in large numbers for subsequent liberation and control of an injurious species. First inklings of such a development are credited to Mokrzecki and Bragina, Russian entomologists, in 1916. (104)

Saticoy, a small town in Southern California, was the point from which the next developments emenated (37, 38, 39, 40, 41). Whether Stanley E. Flanders, entomologist of the Saticoy Walnut Growers Association, got his original idea from Mokrzecki and Bragina is hard to say. However, he was the man who demonstrated, to the satisfaction of leading entomologists, a unique process for assisting "Mother Nature" in a task of mass production --or rather reproduction--of that practically cosmopolitan and sporadic egg parasite Trichogramma minutum Riley, a parasite so small that one has to look twice to see it with the naked eye; but nevertheless one that has, at various times, been the destroyer of over 100 different species of other insects.

Mr. Flanders set about building what could be called, from a popular standpoint, a Trichogramma nursery --perhaps factory might be the better term. In the end he developed a mthod that would produce a million of these insects in a day, in a building only 25 x 36 ft. in floor space.

Before considering the experiments of the writer with Trichogramma minutum, and the work of other investigations, let us first consider the parasite from a distributional and systematic standpoint.

DISTRIBUTION.

Trichogramma minutum stands as a supreme example of cosmopolitanism in the insect world, both from a geographic (54) and a host standpoint (100). It is found in all five continents, and in practically all the countries of these continents where entomologists have worked.

The insect is found in the western hemisphere in Canada, United States, Mexico, West Indies, Central America, and South America. In the eastern hemisphere it is found in Eurasia in the British Isles, France, Belgium, Germany, Italy, Austria-Hungary, Serbia, Russia, India, Burma, and Ceylon (recently imported). (94) It also occurs in Australia, New Zealand, the Hawaiian Islands, and South Africa. In each of the foregoing localities Trichogramma parasitizes one or more hosts.

HOSTS.

Only a few species are found in the family in which Trichogramma minutum belongs, but together they attack and parasitize insects in practically every order, (100). All of them have very large host lists, but T. minutum seems to considerably outstrip the others. It has been reported as parasitizing well over 100 hosts in six different orders: Lepidoptera , Coleoptera, Hymenoptera, Neuroptera, Diptera, and Hemiptera.

All records indicate that Lepidoptera are the most favored hosts, with Diptera and Hymenoptera ranking next.

Girault's (57) discussion of hosts is slightly contradictory. In the same reference he makes the statement that all Trichogramma host larvae "feed upon foliage of various trees and plants--none are wood-boring, carnivorous, or predaceous in the larval stages," and then lists Chauloides rastricornis Rambur, from the order Neuroptera, the larvae of which are predaceous.

Only one family of the order Diptera, the Tabanidae, is subject to the inroads of the parasite. It was not until 1926 that these flies were reported by Cameron (20) as hosts.

The following host list is not complete. For one thing new hosts of T. minutum are still being discovered Publications of some host records are either obscure or incomplete. It is probable that Trichogramma will try to oviposit in almost any insect egg. According to Flanders (41) it has been known to attempt oviposition in the juice globules of okra plants, the swollen abdomen of Pediculoides mites, and in paper smeared with the hair covering of the egg masses of the browntail moth. Its oviposition is confined to the eggs of all the following species:

ORDER COLEOPTERA.

Family Chrysomelidae.

1. Donacia simplex Fab. (50)

2. Odontota suturalis Thunberg. (100) (135)

3. Odontota dorsalis Thunberg. (100)

4. Metriona bicolor Fab.

5. Metriona signifera Herbst.

ORDER LEPIDOPTERA.

Family Papilionidae.

1. Papilio glaucus Linn. Tiger Swallowtail. (100) (84) (135)

2. Papilio glaucus turnus Linn. (100) (84)

Family Nymphalidae.

1. Agraulis vanillae Linn. (100)

2. Aglais milberti Godart. (100)

3. Dione vanillae Linn. Gulf Fritillary.

4. Polygonia interrogationis Fab. (160)

5. Basilarchia archippus Cramer. Viceroy Butterfly. (100) (120) (135)

6. Vanessa atlanta Linn. Red Admiral. (36) (135)

Family Nontodontidae.

1. Datana intergerrima G. and R. Walnut Caterpillar. (100) (93) (124)

2. Datana ministra Drury. Yellow-necked Caterpillar. (59)

3. Ianassa lignicolor Walk. (100) (36) (55)

Family Hesperiidae.

1. Calpodes ethlius Cramer. Canna Leafroller. (100)

2. Gonius proteus (Linn). (100) (59) (88)

3. Prenes nero Fabr. Skipper. (90)

4. Prenes ocola Edw. (90)

5. Thanaoa lucilius Lint. (100)

Family Pieridae.

1. Eurymus eurytheme Boisd. Alfalfa Caterpillar. (100) (36) (138)

2. Eurymus interior Sand. (100)

3. Pieris rapae (Linn.) Cabbage Butterfly. (100)

Family Tortricidae.

1. Archips rosaceanae Harris. Oblique-banded Leaf Roller. (100)

2. Homona cofferia. (94)

3. Laspeyresia prunivora Walsh. Oriental Peach Moth. (45)

4. Laspeyresia pomonella (Linn.). (100)

5. Platynota rostrana Walk. (100) (55)

6. Tortrix citrana Fernald. (100)

7. Tortrix fumiferana Clemens. (100)

Family Arctiidae.

1. Estigmene acraea Drury. Salt Marsh Caterpillar. (36) (59)

2. *Hyphantria cunea* Drury. Fall Webworm. (100) (42)

3. *Hyphantria textor* Harris. (100)

4. *Utetheisa ornatrix* Linn. (133)

Family Ceratocampidae.

1. *Anisota senatoria* S. and A. (100) (59)

Family Sphingidae.

1. *Ceratoma catalpae* Bois. (100) (59)

2. *Protoparce sexta* Johan. Tomato Worm. (100) (36) (68)

3. *Isogramma hageni* Grt.

4. *Smerinthus* sp. (100)

Family Lymantriidae.

1. *Euproctis chrysorrhoea* Linn. Browntail Moth. (100) (42) (82)

2. *Olene pinicola* Dyar. (57)

Family Satyridae.

1. *Oeneis macounii* Edw. (100)

Family Eucosmidae.

1. *Bactra lanceolana* Hbn. (59)

2. *Bactra furfurana* Haw. (59)

3. *Carpocapsa pomonella* Linn. Codling Moth. (Reared) (31) (41)

4. *Eudemis vacciniana* Pack.

5. *Evetria montana* Busck. (100)

6. *Polychrosis botrana* Schiff. (55)

7. Polychrosis viteana Clem. (55) (86)

8. Tmetocera ocellana D. and S. Bud Moth. (33) (35) (63)

Family Noctuidae.

1. Alabama argillacea (Hbn.). Cotton Leaf Worm. (100) (36) (105)

2. Autographa brassicae (Riley). Cabbage Looper. (100) (36) (55)

3. Caenurga erechtea Cram. Forage Looper. (129)

4. Ceramica picta (Harris). Zebra Caterpillar (36)

5. Heliothis obsoleta Fabr. Corn Ear Worm. (100) (27) (36)

6. Laphygma frugiperda S. and A. Fall Army Worm. (100) (36) (55)

7. Lycophotia margaritosa Haw. Variegated Cutworm. (Reared)

8. Anytus cupola Hamp. (125)

9. Mamestra picta Harris. (55)

10. Omiodes meyricki. (100)

11. Omiodes blackburnii. (100)

12. Omiodes accepta. (100)

13. Peridroma margaritosa caucia Hub. (100)

14. Platypena scabra Fab. (100) (125)

15. Spodoptera mauritia. Nut Grass Army Worm. (130)

16. Cosmophila erosa (Hub.). Mallow Caterpillar (30)

Family Gelechiidae.

1. Sitotroga cerealella Oliv. (Reared) (41) (68)
2. Phthorimaea operculella Zell. Potato Tuber Worm.

Family Pyralidae.

1. Acrobasis molesta. Pecan Leaf Case Bearer. (52)
2. Chilo simplex. Rice Borer. (21) (147)
3. Chilo plejadellus Zinck. (85)
4. Chilo epia Dyar. (21)
5. Diatraea saccharalis Fab. Sugar Cane Moth Borer. (1) (9) (10)
6. Diatraea striatalis Fab. (15)
7. Diatraea auricilia. (21)
8. Diatraea zeacolella Dyar. Large Corn Stalk Borer. (113)
9. Diatraea idalis Fern. (7)
10. Ephestia kuehniella Zeller. Mediterranean Flour Moth. (Reared) (134)
11. Phylctaenia ferrugalis Hbn. (100)
12. Plodia interpunctella (Hbn.). Indian Meal Moth. (41)
13. Pyrausta nubilalis Hub. European Corn Borer. (100) (5) (18)

14. Mineola vaccinii Riley. Cranberry Fruit Worm. (42) (44)

ORDER HEMIPTERA.

No species of Hemiptera are listed in literature as being parasitized by Trichogramma minutum, but C. O. Bare, of Tampa, Fla., claims to have bred it from hemipterous eggs.

ORDER NEUROPTERA.

Family Chrysopidae.

1. Chrysopa spp. (100)

Family Sialidae.

1. Sialis infumata Newm. (100)
2. Chauloides rastricornis Rambur. (100) (57)

ORDER DIPTERA.

Family Tabanidae.

1. Chrysops mitis O. S. (100) (20)
2. Chrysops moerens Walk. (100) (20)
3. Chrysops striatus O. S. (100) (20)
4. Chrysops excitans Walk. (100) (20)
5. Tabanus phaenops O. S. (100) (20)
6. Tabanus punctifer O. S. (100) (20)
7. Tabanus lasiophthalmus Macq. (100) (20)

ORDER HYMENOPTERA.

Family Tenthredinidae.

1. Ametastegia glabrata Fallen. Dock Sawfly. (36) (106)
2. Caliroa aethiops Fabr. European Rose Slug. (100) (83)

3. Caliroa obsoleta Norton. (100)
4. Cimbex americana Leach. Elm Sawfly. (42) (108) (128)
5. Eriocampoides limacina (Retz.). Pear Slug (100) (32) (34)
6. Pachynematus palliventris Cress. (100) (55)
7. Pteronidea ribesi Scop. Imported Currant Worm. (100) (36) (48)

SYSTEMATIC CONSIDERATION.

Description and Synonomy.

The parasite was first observed, from a systematic standpoint, by Riley in 1871, in the state of Miss. At that time he did not publish what might be termed an original description. He at first called the insect the Disippus egg parasite, after the host from which he bred it--Limenitis disippus Godt., since found to be synonym of Basilarchia archippus Cramer, the Viceroy Butterfly, of the family Nymphalidae. Soon after, however, he named it Trichogramma minutum, but added that he would leave the proper description to those entomologists who pay more particular attention to the family Chalcididae.

Riley's description, given at time of naming, still stands as original (120): "It comes nearest the genus Trichogramma, Westw., and may be provisionally called Trichogramma minuta. It differs from that genus and from all other Chalcididian genera with which I am acquainted, in the antennae being but five-jointed (scape, plus four joints), the scape stout and as long, or longer, than joints two, three, and four together; joints three and four small and together as long as joint two; five very stout, fusiform, and as long as two, three, and four together. The legs have the trochanters stout and long, the tibiae not quite so long nor so stout as the femora, and with a long tooth; the tarsi are three-jointed, with the joints of equal length and with the claws and pulvilli sub-obsolete. The abdomen is apparently six-jointed, the basal joint wide, the seond narrower, two to five increasing in width till five is as wide as one. The ovipositor of the female extends a little beyond the apex, and starts from the anterior edge of the fifth joint."

The foregoing description is found in Riley's "Third Report on the Insects of Missouri," page 158, 1871. This may be regarded as the original description as it tallies word for word with the description given by Riley in 1881, ten years later, under "General Index and Supplement to the Ninth Report on the Insects of Missouri," bulletin number 6, page 68.

After Riley's first unofficial description of T. minutum he proposed for it the generic name Pentarthron (121). This name had, however, been used by Wollaston in beetles; so Riley retained the old generic name.

A large number of synonymic species cannot be claimed for T. minutum, in spite of its extensive distribution. The following determinations are listed as synonomous:

Pentarthron minutum (Riley).

Trichogramma minutissimum Packard.

Trichogramma pretiosum Riley.

Trichogramma intermedium. Howard.

Trichogramma odonototae Howard.

Types of the species in synonomy were lost or never deposited, according to Marton (100).

Classification.

Riley first placed T. minutum in the family Chalcididae, but it is now placed in the family Trichogrammatidae by practically all authors. This family is a small one, according to most authorities. However, there is great diversity in the different references in the number and placing of genera and species within the family. Viereck (135) assigns to the family only two genera, Trichogramma and Lathromeris, with a total of five species, only one being listed under Lathromeris. Essig (36) places two other genera in the family besides Trichogramma, Abbella and Oligosita. Cresson (26) treats the family as a subfamily--Trichogramminae--and includes the following genera: Ophioneurus Ratz., Trichogramma Westw., Chaetosticha Walk., Lathromeris Forst., Centrobia Forst., and Oligosita Hal.

Other authorities vary just as much. The writer does not feel justified, therefore, in presenting a key to species taken from any one, or even two or three authorities, in the face of so much difference of opinion.

One might start with the suborder Clistogastra or Apocrita, within the order Hymenoptera, to show just where T. minutum stands in the Linnean classification scheme. In this suborder the second abdominal segment, which appears as the first, is constricted to form a slender petiole or waist between the large portion of the abdomen and the wing-bearing region of the body. To this suborder belongs the superfamily Chalcidoidea, composed of an extremely large number of insects, many as yet undescribed, of exceedingly small size, the majority of which are parasitic. The anterior wings, sometimes wanting, are almost devoid of veins (Pl. II); they have neither a marginal cell or a distinct basal cell, the latter, if at all indicated, usually poorly defined by hyaline veins only visible by transmitted light. The hind wings have, as a rule, a short submarginal vein. The antennae are elbowed.

In the family Trichogrammidae, or Trichogrammatidae, as spelled by some authorities, the tarsi are three-jointed; the pubescence of the wings is arranged in line; the fore tibia has a delicate straight spur; the ovipositor issues cephlad to the apex of the abdomen; the antennae are rarely without ring joints; in the anterior wing the submarginal vein reaches the costa.

Members of the genus Trichogramma, erected by Westwood, are characterized by having eight-jointed antennae; the submarginal, marginal, and stigmal veins forming a regular arch; the submarginal vein reaching the costa; the anterior wings with regular rows of hairs.

In all there are about eight species belonging to the genus Trichogramma, but only the following appear to be native to this country: T. minutum Riley, T. ceresarum Ash., T. flavum Ash., and T. evanescens Westw.

CHARACTER OF Trichogramma minutum.

Since T. minutum kills its host before it ever has a chance to hatch and feed, it must be considered as one of the most efficient destroyers of injurious insects.

From an entomological viewpoint T. minutum may be termed a parasite but this classification can be modified. It may also be termed, along with most of the other insect parasites of insects, an internal predator. It destroys all but the egg shell of the host within 15 to 24 hours after hatching. Such comparisons between the parasite and internal predator are a bit "far fetched" as no exact definition of a parasite fits all cases.

Adaptability to Biological Control Work.

Flanders discusses the advantages--biotic responses of Trichogramma minutum. Most of his points apply also to Oregon conditions:

1. The parasite mates and oviposits readily in confinement.

2. It develops to maturity in the grain moth eggs, one individual per host egg.

3. It has a shorter life-cycle than any host.

4. It has a more extended development range than its hosts.

5. It has a great variety of hosts and, according to Dr. Hase (64) no host preference.

6. It is capable of outnumbering its hosts.

7. It accomodates itself to its host's generation.

8. It will develop throughout the year, with proper temperature and food.

9. It has few competing species and no secondary parasites.

10. Its dispersal is so localized that its effectiveness is measurable.

11. The parasites effectiveness is determined by its abundance on the food plant of the host and by the amount of host material within its sphere of action.

12. Its large host list makes it easy to raise in the laboratory, for it can be switched to other hosts if necessary.

Factors which limit the usefulness and adaptability:

1. *Trichogramma* does not appear to be specific as to host location.

2. The parasite is prey to such predators as ants, lady-bird beetles, mites under natural conditions when in the host. A 10 per cent mortality due to predators may be expected. If more than one parasite develops within a host egg the first to emerge leaves and opening through which predaceous insects, especially mites, may enter. Predatory mites are limiting factors in large scale production.

3. A parasite with polyphagous habits is not as effective as one with restricted host preference and life history adjusted to that of its host. The fact that *Trichogramma* has a shorter life cycle than practically all its hosts is without doubt one of the causes of its polyphagous habits. These habits are also influenced by the immunity of the parasite to all its hosts internal juices, as is not the case with many other parasites.

4. Its power of dispersal in apple orchards is poor. At the present time this appears to be it most important drawback.

A considerable variability of occurrence of *Trichogramma* from year to year, and even from season to season, has been noticed in connection with hosts other than the codling moth. Caffrey and Worthly (19) found this to be so in the case of the European corn borer.

In some years they would get as high as 70 to 80 per cent parasitism, while in others the percentage would be as low as 10 to 20 per cent. They also noticed that at the first of the season--in the spring--Trichogramma was hardly a factor in control, but in later generations, towards fall, it became very effective. Jones (87) had practically the same experiences with the corn earworm. Somewhat the same variability was also noticed in connection with parasitism of the alfalfa butterfly.

The question as to whether climatic conditions in Oregon would be suitable to rapid development of the parasite was one that was given consideration. This point has already been solved for the Hood River Valley, where an average of 3 per cent native parasitism by Trichogramma on codling moth was found during the season of 1929. The parasite has also been well represented in previous seasons, according to Leroy Childs, superintendent of the Hood River Experiment Station. In the Willamette Valley the question of climatic adaptability of Trichogramma is still a moot question, owing to the fact that no field liberations and tests were made, and that very few native specimens have been recovered. Jones (87) found that a late wet spring was very detrimental in the case of parasitism of the European corn borer by the insect.

Franklin of Massachussetts (43) corroborates the facts regarding cold wet weather. From extensive counts made for the parasite on eggs of the cranberry fruit worm he found that there was 25 to 75 per cent parasitism of the fruit worm on dry cranberry bogs, and from none to 70 per cent on those bogs with winter flowage. He stated that there was a great reduction of the parasites on the flowed bogs due to the long period of wet weather in the first part of the season.

## LIFE HISTORY AND HABITS.

### General Remarks.

*Trichogramma minutum* is an egg parasite, the body of the adult measuring only .35 mm. in length. Its small size, coupled with the fact that its complete development takes place within the egg of its host, makes it hard to secure accurate observations of the various changes in its life cycle. If the observations on some of the stages are not very complete these facts, and also the fact that the time for observations was somewhat limited, will have to be taken into consideration.

### Mating and Oviposition.

Both copulation and oviposition take place very soon after emergence, especially on sunny days. The female was observed to be almost passive during the act of mating. The male is persistent, and quite polygamous. He may unite with the same female, or with other females, two or three times within a few seconds. The male assumes a peculiar during the act. After grasping the female's wing tips with his front pair of legs he assumes an inclined or "underslung" position, at an angle of from 60 to 70 degrees, with the tip of his abdomen well under the venter of the female. The act lasts from two to five seconds. The pair usually are motionless, but at times run about.

Girault (55), after an examination of 763 specimens of T. minutum, reared throughout the whole season from a great variety of hosts, found that the sexes existed in about equal proportions, with just a slightly greater proportion of females. There appears to be no difference as to the relative time of issuing of the sexes.

The females, as a rule, are larger than the males, but this does not always hold true, and cannot be relied upon to distinguish between the sexes.

The eggs of T. minutum are deposited inside the egg of the host, sometimes as high as five in number, but usually only one or two. The female Trichogramma walks over the host egg until she finds a suitable spot for oviposition. Her wings are then raised and her abdomen lowered until her ovipositor can be inserted in the chorion of the egg. A slight backward and forward "sawing" movement is at first noticed, but the insect remains quiet for the greater part of the time that she has her ovipositor inserted.

According to Holloway (94) he was able to obtain oviposition of *Trichogramma* females in the juice globules of okra plants. One would think, then, that the parasite would oviposit in practically any insect eggs. Martin claims (100) they will not oviposit in Donacia or grynid eggs, and Howard and Fiske (82) state that it is often a physical impossibility for them to oviposit in the eggs of the brown-tail moth.

The duration of the act of oviposition averaged about 27 seconds under laboratory conditions, according to a series of observations. All the females observed were in petri dishes, and were watched in the act at different times of the day. The host eggs were those of *Sitotroga cerealella* Oliv., shellaced on cardboard discs. The majority of observations were on different females--females watched in different petri dishes, and from three different "hatches" of parasites.

| Observation No. | Time of Day. | Duration of Oviposition. |
|---|---|---|
| 1. | 9.30 A. M. | 27 seconds. |
| 2. | 9.40 A. M. | 24 seconds. |
| 3. | 3.00 P. M. | 21 seconds. |
| 4. | 3.20 P. M. | 29 seconds. |
| 5. | 3.30 P. M. | 27 seconds. |
| 6. | 5.05 P. M. | 29 seconds. |
| 7. | 10.45 P. M. | 34 seconds. |
| 8. | 12.10 P. M. | 30 seconds. |
| 9. | 12.30 P. M. | 25 seconds. |
| 10. | 2.45 P. M. | 25 seconds. |

Quaintance and Brues (116) found that the time for egg deposition was considerably longer than the average for the foregoing table--two minutes being required for the laying of each egg in the egg of the cotton bollworm. Martin (100), however, found that only and average of about 22 seconds was required for oviposition in eggs of *Sialis*.

The number of parasite eggs deposited in each host egg depends considerably on the size of the latter. Few observations were made by the writer on this phase of oviposition. In parasitized codling moth eggs at Hood River two and sometimes three parasites were found in one egg; four were very rare. Ainslie (3) reports rearing as many as 10 adults from the eggs of *D. saccharalis*. In the case of the bud moth Du Porte (33) says that there is seldom more than one parasite per egg. Jones and Wolcott (90) also claim to have bred large numbers of adults from the eggs of the skipper *Prenes nero* Fab.--7 to 11 adults often emerging from a single egg. Smaller eggs, as a rule, seem to have fewer parasites per egg, but this does not always hold true.

Oviposition is naturally most frequent and continuous during the first half hour of the parasite's life. During the next hour and one-half it drops off somewhat. From two hours on the length of time between depositions increases very rapidly. About 40 eggs per female is the average number laid during the two hour period.

It was observed that Trichogramma females oviposited in Sitotroga eggs at almost any stage in their embryonic development. This phenomena is corroborated by Girault's (54) findings. He raised adult parasites the eggs of which had been deposited in eggs of Heliothis obsoleta only eight hours before they were due to hatch. Girault's experiments indicate that parasitization is successful up to time of exclusion of the host from its egg.

Reaction of the Host to the Parasite.

The reaction of the Sitotroga and Carpocapsa embryos to Trichogramma was a phase of the parasitism that was almost impossible to make observations on. Sitotroga eggs that showed several days development were exposed to mated females in petri dishes. There was no trouble in obtaining oviposition. The opaque chorions of the host eggs would not clear up sufficiently, even when exposed to the action of excess amounts of potassium hydroxide and Bouin's clearer and fixer, to show any appreciable reaction or change in the unattacked host tissues. Even the parasite larva, being so nearly the color of the host tissues, and having such a poorly-defined epidermis, would not show up to any extent in slides of the grain moth eggs. Pupal stages of the parasite, however, showed up quite clearly in later slides (Pl.IV-2). Another hinderance to the study of embryonic reaction to the parasite was the fact that the larva of the latter devours the tissues within the host in such a short time--from 15 to 26 hours. This makes extended observations quite difficult.

The Egg.

The eggs of Trichogramma minutum, dissected from grain moth eggs, were found to be very perishable objects that collapsed and shrivelled up almost at once if not kept in some liquid, or at least in a very moist condition.

Eggs of the parasite averaged .115 mm. in length and .034 mm. in width. A general oval shape predominated in most eggs examined, with often a slight broad appearance at one end (Pl. III). The dissected eggs were of rather uncertain outline, and almost colorless.

The period of incubation of the egg could not be determined. Probably it is less than 24 hours, with a considerable variation due to temperature and humidity.

The Larva.

The parasite larva is, like the egg, almost colorless. It is characterized by an almost complete lack of appendages. In fact the writer was never able to observe the "oral hooks" that Martin (100) characterizes as the only appendages that the larva possesses. The mouth opening, however, was found after some search in most of the specimens examined. The whole grub has an irregular sac-like appearance, filling the cavity in which it is found in the egg. The average length is .122 mm.

Gatenby (50) says that in Trichogramma evanescens the tracheae, ordinary mouth parts, heart, and oesophageal valve are wanting. Martin (100) has found the same absences in the case of T. minutum.

According to Martin (100) the larva rapidly swallows the contents of the host egg, cramming all tissues into its sac-like body. The body wall of the larva becomes thinner and thinner as additional material is taken in, until the parasite larva fills the host egg.

The larva and egg stage combined cover a period of from four to seven days, depending on humidity and temperature, and on the host. In Sitotroga this combined stage averages two days less than for C. pomonella.

The Pupa.

The pupa, when first formed, is of yellowish-white color. In size the body of the pupa is often as large or larger than the adult. It averages about .37 mm. in length. The general color is light yellow at first, gradually turning darker until the blackness of the adult is reached. The pupal stage lasts from two to four days.

Trichogramma host eggs present a very characteristic black appearance when once the pupal stage of the parasite has been reached. There is also a peculiar black sheen that distinguishes practically all eggs that contain the parasite.

<u>The Adult.</u>

The parasites issue from the host eggs as adults through one or several holes cut by their jaws. The hole has jagged edges as a rule, but is rounded in outline (Pl. VII). The large majority of the adults emerge through single exit holes--about 89 per cent according to Girault (<u>55</u>). In an examination of Angoumois grain moth eggs 41 parasites issued from 27 host eggs, and from 33 exit holes; so it can be seen that in a good many cases two or more emerge from a single host, and use the same exit hole.

It was found that the position of the exit hole in the host egg varied. The hole was either cut at one end of the egg, or else was found on the upper side. The holes varied in size as well as shape. They were either large, irregular, and jagged, or they were quite small--seemingly almost too small for the parasite to emerge.

Hungerford (<u>83</u>) found that the time required for the <u>Trichogramma</u> adult to cut the emergence hole in the case of eggs of the European rose slug was about 30 minutes in some cases, but usually considerably less time was spent in the operation. Where more than one adult is present in the egg the second will sometimes enlarge the opening with its mandibles.

Emergence of one brood of parasites is sometimes spread over a period of 24 hours. This is a long period when the rapidity of the other changes in the life history of the parasite are taken into consideration.

The parasites are capable of jumping over an inch before the wings are dried and filled out. They are often quite active during this period of drying.

Brachypterous and Wingless Specimens.

A few wingless and quite a number of short-winged specimens of *T. minutum* were reared in the laboratory, both at Corvallis and at Hood River. Some of these specimens were bred from material received from Flanders and Dr. Jones, but the majority were from the writer's own stock. (Pl. I-2)

According to Girault (55) a number of these short-winged specimens are not truly brachypterous. Their wings are simply folded back and often take a considerable time to unfold in the normal manner. Girault does not mention the completely wingless form, but Hintzelmann (73) devotes considerable space to its discussion in the case of *Trichogramma evanescens*.

Length of Life of Adults.

Observations on length of life of adults after they had emerged in the laboratory, and comparisons with length of life in the field were made. The average longevity of adults for 10 different petri dishes, comprising different generations, was 39 hours where no food was given. In the cases where food was supplied

--thick cotton threads were saturated in honey and water mixture and placed in petri dishes--the life of the adults was prolonged but very little--only about two hours. On more than one occasion in the orchard adult parasites were found on apple trees searching for codling moth eggs over 60 hours after they had been liberated. Hase (64), however, claims that the adults of T. evanescens will live for 30 days if well fed on sweet substances.

Parthenogenesis and Strains.

Few authorities discuss parthenogenesis in connection with the life history of the parasite, possibly because it is hard to observe. Howard and Fiske (82) have found, however, that it does occur, and that the American form of Trichogramma produces 100 per cent males, and the European form either all males or else both males and females.

In his consideration of strains of Trichogramma Marchal (98) does not include Trichogramma minutum, but he suggests that a number of strains in different parts of the country may be found in any species of Trichogramma, the formation of which has been helped by thelyotokus parthenogenesis. T. cacoecia has only two generations per year in Tortrix rosana, the first generation being wingless. The reproduction in this case is entirely parthenogenetic. The number of generations is increased for this species when it attacks <u>Barathra brassicae</u>, and what looks very much like a new strain is produced.

<u>Effect of Light on Emergence and Parasitism.</u>

The following experiment was performed to determine the effect of light on the emergence of adult parasites: Eight cards of parasitized grain moth eggs were brought out of storage at the same time. Four of these cards were placed in a cupboard where no light could get at them, and the other four were left in the open in the laboratory. The temperature was the same for both locations. Two hours after the removal from storage the parasites in the open began emerging. Emergence was fairly rapid at first, but slowed down after the fourth hour. From that time until 14 hours later the parasites continued to emerge. No parasites had emerged from the covered cards eight hours after they had been taken from storage. At the beginning of the ninth hour the cards were taken out of the cupboard and placed in the open along with the other parasites. Emergence started about one-half hour later, and was completed in something less than six hours.

Walcott (<u>143</u>) brought some similar habits of <u>T. minutum</u> to light in 1918. His host was <u>D. saccharalis</u>. Out of 1,506 egg clusters collected, 63 per cent were parasitized by <u>T. minutum</u>. In some way he figured the normal time for emergence of adults from this lot as two hours after sunrise. He then delayed emergence for part of these by placing them in the dark. Six times as many adults of Trichogramma emerged in the first hour after being exposed to daylight as emerge in the dark per hour.

Voelkel (136) found that a parasitism of Pieris brassicae Linn. and Barathra brassicae Linn. amounting to 78 to 100 per cent in the sun, and only 38 to 55 per cent in the shade was found to be the case near Berlin.

How Trichogramma Overwinters.

The question of how T. minutum overwinters is one that does not appear to have been solved by any other workers who have investigated the biology of the parasite. Howard and Fiske (82) have published temperature results that tend to show how the insect spends the winter. If the temperature falls below certain limits the parasites will hibernate in the pupal stage in host eggs. From then on their development may be delayed several weeks, even months, although exposed to continuous high temperatures.

Codling moth eggs at Hood River were found parasitized by Trichogramma as late as Sept. 24, 1929; so it seems more than likely that they would hibernate throughout the winter within this host. It is quite probable, however, that some of the parasites that attacked codling moth eggs earlier in the season changed to other lepidopterous hosts for hibernation.

Geotaxis in *Trichogramma*.

Martin (100) claims that *T. minutum* is negatively geotactic, but Girault (58) seems to have proved rather conclusively that it is positively geotactic by simply inverting a glass jar up which one of the parasites was crawling in the presence of light. The parasite immediately turned as the jar was turned and continued to crawl upwards. These geotactic movements were repeated as often as the jar was reversed. The insect is always found at the top, or else crawling to the top, of window panes or other glass. It also exhibits a certain amount of positive phototaxis--turning toward greater brightness.

Resume of Life History.

The *Trichogramma* eggs are deposited inside the host eggs and hatch in from 18 to 50 hours, depending on host, temperature, and humidity. The larval and egg stage combined last from four to seven days. The pupal stage lasts from two to four days.

The whole life cycle of the parasite lasts from 8 to 15 days, or longer, depending on host and temperature.

From six to nine generations of the parasite per season occur in the orchards at Hood River on codling moth.

The life history of the parasite is rather well adapted to the life cycle of the codling moth at Hood River. The adults of the latter have such a long period of oviposition that the egg stages of the first and second generation almost overlap. In addition the oviposition of second generation moths continues until on in September. This long egg period of the host does away with any changing of Trichogramma to some other host.

COMMERCIAL REARING OF Trichogramma minutum.

Hinds and Spencer (72) give L. D. Cleare credit for being the first entomologist to develop a method of breeding up the indigenous Trichogramma minutum. With all due respect, however, to Mr. Cleare, most of the credit for a method of commercial rearing of the insect in large numbers must go to Stanley E. Flanders, entomologist for the Saticoy Walnut Growers Association. Flander's method will therefore be described, and given as a basis from which all other methods are treated.

Flander's Rearing Methods. (37, 38, 39, 40, 41).

Mr. Flander's laboratory at Saticoy was small--about 23 ft. by 26 ft. of floor space with two rooms, In the back room, which contains mechanically controlled heat and ventilation, Sitotroga cerealella, the alternate laboratory host is raised. Here there is a stack of shallow bins, 4 inches deep, packed with large white shelled corn, infested with the grain moth. Each bin holds about 125 pounds. The top of each bin is made of narrow slats, one-eighth inch apart. When these bins are stacked there is room enough for the moths to escape from between them.

Thousands of moths escape from the bins each day, and are collected with a vacuum collector, with a collecting chamber between the nozzle and suction fan. Suction velocity is regulated by a gate in the nozzle so that the velocity is low enough not to injure the moths. "The moths are drawn into a 1½ inch hose 17feet long and thence into a receptacle consisting of a gallon battery jar containing an interiorly directed truncated celluloid cone and a tin cover six inches in diameter and four inches high. The cover is provided with an inlet terminating a short distance above the smaller end of the cone and below a horizontal wire screen, above which is an outlet that connects with the source of partial vacuum. The moths are prevented from passing out of the receptacle by the wire screen and are retained in the jar by the cone. The jar can be removed from under the metal cover without loss of moths."

After the jars are shaken sharply, causing the moths to settle to the bottom, they are dumped into the egg-laying chamber. These deposition cages are smooth cardboard cylinders, eight inches high, capped on each end by 20 mesh wire screen, which allows many of the male moths to escape. Enough moths are put in each chamber to fill the bottom to about one inch--or until light no longer filters through.

The deposition cages are then set over a truncated trough beneath which is placed a sheet of paper to catch moth eggs as they drop through. A mild current of air is circulated beneath the cages to carry away the moth debris.

Equipment for preparing the eggs for parasitism consists of 18 and 30 inch mesh wire strainers, moth rinsing jar, filter paper and funnel, shellac and brush, and cardboard discs 3½ inches in diameter, with a ¼ inch aperture in the centre.

The grain moth eggs are sprinkled over the little pasteboard discs, which have been freshly coated with the shellac. Roughly 25,000 eggs are sprinkled on each disc.

One of the discs of eggs is placed in a petri dish along with one-third of a similar disc of eggs that had been parasitized by Trichogramma about eight days before. The Trichogramma adults, some of which have already emerged, parasitize the complete disc of new eggs.

Mailing tubes are used by Mr. Flanders for the storage and shipment of the parasites. Shipments are made at the time when the parasites first enter the pupal stage.

A humidifier is set in operation when the humidity of the moth enclosure goes below 55 per cent. "The apparatus consists of a flattened sheet iron funnel about 30 inches in length. A fine stream of water under high pressure is injected through a small opening in the ventral side.

This is broken into a spray and vaporized by passing it through an 80 mesh screen. A fan forces the moisture laden air into the moth enclosure through the ventilator. Two wire screens in the funnel serve to collect the excess water in the air and pass it outward. These screens are at the larger end of the funnel and placed about four inches apart; the inner one is made of ordinary fly screening and the outer of 20 mesh screen. A daytime humidity of 80 per cent can be maintained in the moth enclosure."

"The procedure in the daily routine of production as follows:

Once every 24 hours the eggs in the trough beneath the egg cages are collected, screened, and winnowed of moth appendages and scales. The cages are lightly shaken to dislodge eggs adhering to the moths.

The accumulated eggs are then poured onto freshly shellaced cardboard discs and all of the eggs not adhering are shaken off. The shellac at the moment of applying the eggs must be sticky enough to hold the eggs, but not so fluid as to engulf them. It is best applied with a small brush.

After allowing the cards to dry for about a half hour or until the alcohol in the shellac has evaporated, they are placed in the parasite cages for a period of 24 hours with night illumination.

In these cages, prior to the introduction of the new egg card, one-third of a card from which parasites have commenced to emerge is placed to provide the stock required to impregnate at least 90 per cent of the new eggs.

Each stock card is useable for two days, so that a six-fold increase is obtainable.

At the end of 24 hours the new egg cards are removed and suspended on hooks fastened to the lower ends of the corn bins. Three days later the parasitized eggs are black, an indication that the parasites are in the early pupal stage. The cards are then placed in cold storage retaining one-sixth as stock cards.

Following the collection of eggs and the preparation of the parasite cages the day's crop of moths is gathered by means of the vacuum collector and dumped into the egg-deposition chamber.

After remaining in the egg deposition chamber two days, the moths are poured into a wire strainer and rinsed to remove adhering eggs. These eggs settle to the bottom of the container, and the debris rising to the surface is drained off. The eggs are then separated out by means of filter paper from which, after drying, the eggs are easily brushed off. Thousands of eggs are conserved in this manner in addition to those collected daily from beneath each cage."

If the foregoing method and daily procedure is followed out one man can successfully operate Mr. Flander's laboratory and raise one million parasites a day.

Rearing Methods of Other Investigators.

A. D. Cleare. (22)

The method of A. D. Cleare for raising *Trichogramma* as a parasite of the sugar cane borer, *Diatraea saccharalis*, falls far short of The Flanders method when it comes to raising large numbers in the minimum of time and with the least effort. The whole process is characterized by extreme simplicity. Stalks of sugar cane are placed in large screen cages for oviposition by borer moths. When egg masses have been obtained the leaves of the stalks are fastened to the bottom of a smaller wooden box with a glass top, into which the parasites are introduced from vials through holes in the sides. When parasitization is affected the egg masses are either stored or else placed in the field for emergence. The method naturally involves considerable labor, and the output of parasites per day does not reach one-tenth the number that the Flanders method does.

Hinds and Spencer.

Hinds and Spencer (68, 69, 70, 71, 72) have apparently had considerable success in the quantity production of *Trichogramma* at Baton Rouge, La. Field control tests of parasitization of the sugar cane borer from liberations have in certain cases shown 100 per cent parasitism. Dispersal of the parasite, however, has been poor. Natural parasitism is low each spring, increases slowly until July, then becomes very high and effective; so most of the liberations have been made with the object of increasing the early season parasitism.

The method has been marked by the rearing of an increased number of parasites each year. In 1928 more than 16 million parasites were reared, and a large number were liberated. The laboratory is now equipped for quantity production, chiefly owing to encouraging results in 1927 and 1928.

Two rooms are used for rearing of the Angoumois grain moth, each 12 by 16 feet, plastered smoothly on the inside. In the center of each room are tiers of removable trays of corn, each tray with a capacity of one bushel. They are arranged much farther apart on the shelves than are the Flanders trays.

The majority of rearing operations are similar to Mr. Flander's methods in general, although the routine daily procedure varies somewhat.

An ordinary vacuum sweeper is used in the c collection of the grain moths.

The temperature of the rearing rooms is held between 75 and 85 degrees F. by electric heating units and fans, the former controlled by simple bimetallic thermostats.

Ordinary glass Mason jars are used as oviposition cages in place of the Flanders type of egg deposition chamber. The moths are allowed to oviposit at will in the jars, and the eggs are then screened onto glass plates, preparatory to being shellaced to pasteboard discs.

Geo. Wishart. (140, 141)

George Wishart, of the Dominion entomological laboratory, Chatham, Ont., raises T. minutum on a similar scale, and by much the same method as Mr. Flanders employs at Saticoy.

The drawback to the use of Sitotroga cerealella as a laboratory host in Ontario is that climatic conditions are too extreme to allow for natural development of this moth. Heat, therefore, has to be employed during the colder month; so a regular thermostatically--controlled incbator is used to rear the moths in large numbers.

The screens in the bottoms of Wishart's oviposition cages are covered with corn starch in which the moths lay their eggs. The starch is removed from the oviposition cages daily and the eggs separated from it by sifting it through a 60 mesh bolting cloth sieve.

*Trichogramma* is raised at Chatham for the control of the European corn borer.

*Harry Smith.*

Mr. Harry Smith, entomologist in charge at the Citrus Experiment Station, Riverside, Cal., has also engaged in the rearing of *T. minutum*, but on a much smaller scale than did Mr. Flanders at Saticoy.

Mr. Smith used corn for the raising of *Sitotroga cerealella*, and stored it in one large bin, comprising about 64 square feet of floor space. The grain moths were collected by suction from an old vacuum carpet sweeper. The egg-laying chambers and egg cards were similar to those used by Mr. Flanders.

Other investigators interested in the commercial raising of *Trichogramma* are D. W. Jones, entomologist, U. S. D. A. Bureau of Entomology, Arlington, Mass.; Geo. M. List, deputy state entomologist, State Agricultural College, Fort Collins, Colorado; and Howard and Fiske, Gypsy Moth Parasite Laboratory, Arlington, Mass.

*Trichogramma REARING EXPERIMENTS IN OREGON.*

*Reasons for Investigations.*

Investigations of *Trichogramma* rearing methods were undertaken to determine whether the commercial rearing and liberation of the parasite in Oregon could be successfully accomplished, and if so what percentage of control was likely to result from such rearing and liberation, also to determine the most successful and economical method for propogating the parasites at the station.

The work at the Oregon station was conducted during a period marked by the outstanding activity and success of Mr. Flanders in his rearings and liberations of the parasite. The project was not only timely from this standpoint, but also from the point of view of seriousness of the pest that was the object of control--the codling moth.

Location, Material, Methods.

The Angoumois grain moth, laboratory host of Trichogramma, was at first raised at the station laboratory at Corvallis, but, as a gradually increased output of the moth brought about congestion and inconvenience to other members of the department, all the grain moth cages and infested wheat were moved to the east wing of the college greenhouses. The balance of the work was carried on, as formerly, in the research laboratory of the department.

Six wooden frame cages, size 31" by 31" by 31", (Pl. IV) covered with wire mesh screen, with sliding doors and open bottoms, were used for the rearing of *Sitotroga cerealella*. Large wooden containers of shelled corn and wheat were placed in each of the cages for the moths to breed in. About 30 pounds of grain was placed in each of the cages. A thick layer of cellular cotton was placed between the cages and the cage stands. This was a simple way of always keeping the cages tight. In order to keep the grain moths free from the depredations of two predaceous mites, Pediculoides ventricosus Newp., and a species of Gamasid, which threatened to exterminate them, and have exterminated the infestations of other investigators, each cage was finally placed on a frame one foot above the greenhouse table. The legs of each frame rested in baths of oil, and great pains were taken to see that no means were provided for mites to in any other way crawl up to the cages. Before placing the grain in any of the cages Before placing the grain in any of the cages it was first thoroughly fumigated by heating to 160 degrees F. Thousands of grain moth eggs were then microscopically examined and freed from all mites and mite eggs. They were then sprinkled on the grain in the cages.

No regular electric suction collector was used for the collection of grain moth at first, a collector worked by the intake of breath was employed instead. This was a very poor substitute. The regular collector used after the first month's work on the project was made from an old vacuum cleaner, the bottom of which was removed and a funnel and hose inserted over the opening and fastened in with a wax composition material. The hose was attached to a glass collecting chamber, extending from which there was a much longer hose and a glass tube. The amount of suction was regulated by a little metal damper placed over the outlet suction tube where it leaves the collecting chamber. ( Plate VII )

The grain moth egg-laying chambers were cardboard cylinders 8 inches in diameter and 14 inches high, with cheese cloth covering on top and 18 mesh wire on the bottom. These cages were suspended in large glass jars, with the egg-collecting petri dishes on the bottom.

Circular cardboard discs, cut to fit inside petri dishes, with a 1½ inch circular piece cut from the middle, were used to hold the grain moth eggs. A thin coating of shellac on the discs was the adhesive used. Petri dishes were used as breeding cages for the parasites, and as storage containers for the parasitized grain moth eggs. A wire mesh egg strainer, paint brushes, needles, and white paper were used to facilitate the process of winnowing out *Sitotroga* eggs, separating them from moth debris, and pasting them on the cardboard discs.

Propogation of the Laboratory Host.

*Sitotroga cerealella* allows for a larger production of Trichogramma in a shorter time than does *Ephestia kuehniella*, Zell. or any of the other so-called laboratory hosts. Numbers of generations can be raised in the laboratory throughout the year under controlled temperature conditions. Oviposition responses of the adults facilitate the collection of large numbers of eggs from the deposition cages in petri dishes or other glass containers. Each female grain moth deposits about 40 eggs, which hatch and go through a life cycle lasting about 28 days. Egg deposition of the moths is stimulated by tiny crevices. When the moths crowd the bottoms of the egg laying cages their bodies form crevices that stimulate oviposition. The constant shifting about of the insects causes the eggs to sift through the 20 mesh screen on the bottom of the chamber. A gentle current of air also stimulates egg laying.

The routine for the raising of the moths when numbers were at the optimum in the greenhouse cages consisted of collection about every four days with the vacuum collector. Enough moths were placed in the cardboard deposition chambers to congregate thickly on the bottom. Thirty-six hours later the eggs were gathered up in the petri dishes below the cages and winnowed and screened. They were then sprinkled on the freshly-shellaced cardboard discs, in preparation for parasitization. The same method and routine was employed for the propogation of the moths at Hood River, except that there were not so many cages to collect from, and the collecting was not done so often.

The method for keeping the grain moth rearing cages free from mites has also been described. List, Daniels, and Bjurman, after a series of comprehensive tests, advocate the use of dusting sulfur in the grain and about the cages and bins that contain the moth. This treatment has proved very effective in killing the nymphs of both the Gamasid mite of the genus Seius and Pediculoides ventricosus Newp. It does not seem to have a detrimental effect on any of the stages of the grain moth.

Oviposition of Parasite in Sitotroga Eggs.

About 20,000 grain moth eggs are sprinkled on one of the cardboard discs previously described. One-third of a card of parasitized eggs, from which the parasites are beginning to emerge, is then placed in the petri dish with the new eggs. The dishes are kept in moderately strong light for 12 hours. If the parasites still seem active and inclined to oviposit the first full egg card is removed and another one substituted. Usually not more than three cards of eggs will be effectively parasitized from the one hatching of parasites. After oviposition by Trichogramma the eggs are either stored or else kept in the laboratory at temperatures ranging from 78 to 85 degrees F. They hatch at these temperatures in from 7 to 11 days.

Storage of Parasites.

No refrigerator was available in the entomology department for the storage of parasitized grain moth eggs; so permission was obtained to use the ice box in the bacteriology department. The parasites were stored there at various times while the project was underway at Corvallis. Proper cold storage at Hood River was even more difficult to obtain, and was one of the big drawbacks to commercial rearing operations. The cold storage room there was located in the Apple Growers Association building. Several thousand Trichogramma in the pupal stage were placed in this room, but the temperature was so constantly low--33 degrees F.--that not one of the parasites survived. The disaster prevented the liberation of a single stored parasite during the height of the second generation oviposition period of the codling moth. Storage of parasites in a frigidaire machine in a Hood River drug store was arranged, and several cards of parasitized grain moth eggs were placed in the machine, during the months of June and July, 1929. In this case the temperature was too high, for the majority of parasites emerged instead of staying in a dormant condition.

Indefinite storage of this parasite is not understood very well yet, according to a communication from Mr. Flanders, but the most successful results have been obtained with a very variable temperature, between 35 and 42 degrees F. A temperature to correspond somewhat with that experienced in nature will probably result in the lowest mortality figures in storage.

Holloway and Loften (79) also had difficulty in the regulation of storage temperatures to suit the parasite. They found that most of the parasites died when kept in a refrigerator over winter at a temperature of 50 degrees F. In addition, a number of the parasites emerged at this temperature.

Parasite Shipping Experiment.

A short time after the *Trichogramma* project was first started some shipments of the parasitized grain moths were received from Dr. Jones, European Corn Borer Laboratory, Arlington, Mass. At his suggestion observations on the methods employed by different investigators for shipping *Trichogramma*, successful emergence of parasites received through the mails, condition of the insects and the like were made.

Flander's Shipment.

Microscopic examinations of parasites shipped from Saticoy were made the day the shipment was received--June 23, 1928. The parasitized grain moth eggs were received shellaced on a cardboard disc 3½ inches in circumference, and with ¾ inch hole in the middle. Approximately 25, 000 eggs were on this disc.

1. Shipped about June 21, 1928.
2. Time of opening the shipment was 10:30 A. M. June 23.
3. Laboratory temperature, 78 degrees F.

4. Emergence: two Sitotroga larvae and 61 adult parasites were observed within one hour after opening. The parasites continued to emerge until placed in cold storage at 38 degrees F. Even then, a number of adults continued to emerge for about a day.

   The unparasitized Sitotroga had also emerged in this shipment, so the parasites were probably delayed en route, or else Mr. Flanders held them out of storage until the grain moth larvae had hatched.

5. Method of shipping: first class mail (train)

Arlington, Mass. Shipment.

The parasites were received shellaced on cardboard 7-7/8 inches in circumference, with six small holes around the outside. Dr. Jones, entomologist at Arlington, says there are only about 4,000 parasitized moth eggs for each card. Microscopic examinations, counts, and photos (Pl. V-1-2) of the parasites were made. Two shipments were sent.

First Shipment:

1. Shipped Aug. 31, 1928.

2. Time and date of opening: 9:15 A. M.
   Sept. 6, 1928

3. Laboratory temperature, 62 degrees F.

4. Emergence: T. minutum none. S. cerealella--three living larvae crawling about over the eggs; eight dead larvae on the cotton wool.

5. Method of shipping: first class mail (train).

6. Parasitized eggs were not held out of cold storage before shipping.

Second shipment:

1. Shipped Sept. 4, 1928.

2. Time and date of opening: 10:30 A. M., Sept. 7, 1928.

3. Laboratory temperature, 67 degrees F.

4. Emergence: T. minutum none. S. cerealella--four dried up larvae in the cotton wool.

5. Method of shipping: air mail.

6. Parasitized eggs were held out of cold storage until the grain moth larvae had emerged.

The percent of emergence and the condition of the parasites in both shipments was about equal--the parasites shipped by air mail had a 3 per cent advantage in emergence over those sent by train; which would be but a slight advantage for the faster air mail method of shipment.

PROPOGATION AND FIELD LIBERATION TESTS

AT HOOD RIVER, OREGON.

Rearing Operations.

Rearing operations for the production of numbers of *Trichogramma* were almost identical with methods used at Corvallis, except that there were not as many cages used for the raising of the Angoumois grain moth. Collection of the moth for oviposition was also less frequent.

A new vacuum collector had to be purchased and made over into an "insect collector" during the month of July, 1929. This was a big improvement as the old collector was completely worn out.

Method of Securing Parasitism.

One-quarter of a disc of grain moth eggs, which had previously been parasitized by *T. minutum*, was placed with a full disc of new eggs in a petri dish. The emerging adult parasites soon mated and oviposited in the eggs on the new disc.

Laboratory Breeding and Propogation Records.

Records are complete for all parasites handled by the writer in the laboratory during the season of 1929 at Hood River, Ore. Records are for Sitotroga eggs after they have been shellaced on the cardboard discs. (See table number 1).

**Breeding and Propogation Records.** (Table No. I).

| Egg Card No. | Date of Oviposition. | No. of Par. Admitted Per Card. | No. of Eggs on Card. | Date of Parasite Emergence. | Per Cent of Parasitism. | Remarks. |
|---|---|---|---|---|---|---|
| 1. | 7/9/1929 | 3000 | 11,800. | Stored | 84% | Placed in Cold Storage. |
| 2. | 7/9/1929 | 2000 | 12,100. | Stored | 80% | " |
| 3. | 7/10/1929 | 2000 | 11,500. | 7/20/29 | 85% | Liberated |
| 4. | 7/22/1929 | 2000 | 22,500. | 8/2/29 | 72% | " |
| 5. | 7/24/1929 | 1500 | 11,600. | 8/4/29 | 83% | " |
| 6. | 8/14/1929 | 1800 | 11,200. | Card a failure due to mite depredations. | | |
| 7. | 8/22/1929 | 1700 | 11,100. | Stored | 78% | Placed in Cold Storage. |
| 8. | 8/22/1929 | 1700 | 10,000. | Stored | 81% | " |
| 9. | 8/24/1929 | 1900 | 18,000. | Stored | 80% | " |
| 10. | 8/24/1929 | 2000 | 17,000. | Stored | 81% | " |
| 11. | 8/27/1929 | 1800 | 19,000. | Stored | 51% | " |
| 12. | 8/27/1929 | 1300 | 10,000. | Stored | 56% | " |
| 13. | 8/30/1929 | 1950 | 16,000. | Stored | 71% | " |

Parasite Shipments Received From Outside Sources.

A shipment of parasites was received from Herbert Spencer, assistant entomologist, Louisana Experiment Station, Baton Rouge, July 3, 1929. This was to augment the supply on hand at Hood River. Approximately 50,000 parasitized grain moth eggs were in the shipment.

Natural Trichogramma Parasitism--Recovery.

A check by Leroy Childs, superintendent of the Hood River Experiment Station, and the writer on late generation codling moth eggs parasitized by T. minutum showed a natural parasitism of 3 per cent in the experiment station orchards.

Laboratory Observations.

July 23, 1929. Eleven parasitized codling moth eggs, on five apples, were covered separately by thin glass vials. The mouths of the vials were simply pressed into the flesh of the apple, thus sealing all means of exit of the adult parasite when it emerged.

July 29, 1929. Two adults of Trichogramma had emerged in the vials. One was dead.

Aug. 2, 1929. Two adults emerged, both T. minutum.

Aug. 6, 1929. Four adults of T. minutum had emerged. Only one was still alive.

Aug. 9, 1929. The remaining three eggs were dissected. Two dead pupae of T. minutum were found in one egg, and one in each of the others.

Orchard Liberations of *Trichogramma*.

Location.

Mature Newtown apple trees, in the experiment station orchard at Hood River, were selected for liberation experiments. A few trees were also utilized in Mr. Benton's orchard, about three miles S. W. of the station orchard.

Methods.

Liberations of parasites were made by tying one-fourth of a card of parasitized Angoumois grain moth eggs to branches of the apple trees selected. One-half of the cards were tied in the trees by fine copper wire, and the other half by cotton thread. The two methods of hanging the cards were adopted to check on depredations of ants and other predators that might crawl down the cord.

Most of the trees were infested by *Trichogramma* at the rate of one parasite to 14 codling moth eggs.

Check trees adjacent to trees in which parasites were liberated were kept under observation throughout the season.

The following table is a summary of *Trichogramma* liberations for 1929 at Hood River.

<u>T. minutum Liberations at Hood River.</u> (Table No. II).

| Lib. No. | Date of Liberation | No. of Parasites Liberated | Portion of Cards Hung Up. | Codling Moth Infestation. | Location of Tree. | Remarks. |
|---|---|---|---|---|---|---|
| 1. | 7/9/1929 | 4,000. | $\frac{1}{4}$ | Medium. | S.E.Orchard | Unsprayed Check. Hung up by string. |
| 2. | 7/9/1929 | 4,000. | $\frac{1}{4}$ | Medium. | " Same Tree. | " |
| 3. | 7/20/1929 | 4,000. | $\frac{1}{4}$ | Light. | S.E.Orchard | Hung up by string. |
| 4. | 7/20/1929 | 4,000. | $\frac{1}{4}$ | Light. | " Same Tree | " |
| 5. | 8/7/1929 | 3,500. | $\frac{1}{2}$ | Heavy | Central Orchard. | Hung up with fine wire. |
| 6. | 8/7/1929 | 3,500. | $\frac{1}{2}$ | Heavy | " | " |
| 7. | 8/10/1929 | 3,000. | $\frac{1}{4}$ | Heavy | " | " |
| 8. | 8/10/1929 | 3,000. | $\frac{1}{4}$ | Heavy | " | " |
| 9. | 8/14/1929 | 4,000. | $\frac{1}{2}$ | Medium | Benton's Orchard. | " |
| 10. | 8/27/1929 | 3,800. | $\frac{1}{2}$ | Medium | " | " |



A total of 36,800 parasitized grain moth eggs were set out. From counts of emergence holes in *Sitotroga* eggs over a series of the parasitized cards in the orchard there was an average of 81 per cent parasite emergence, or 29,808 adults of *Trichogramma*.

First Control Experiment.

The approximate percent of infestation for three Newtown apple trees, closely located in the S. E. orchard of the experiment station, was estimated before July 1, 1929.

Two of the trees were used for liberations of T. minutum, the other being used as a check tree.

Data on location of the control trees, per cent of codling moth infestation, number of parasites liberated per tree, spread of parasite infestation, and the check on the amount of parasitism are shown in table number III.

Second Control Experiment.

Materials and methods were the same as the first, only the experiment was in a different location. Results are shown in table III.

Third Control Experiment.

Material and methods were the same as in the first and second experiments, with the exception of the location, which was in Mr. Benton's orchard. Results are shown in table number V.

First Control Experiment. (Table No. III).

| Tree Numbers. | | 1. | 2. | 3. |
|---|---|---|---|---|
| Location. | | S.E. Orchard. | S.E. Orchard | S.E. Orchard. |
| Variety. | | Newtown. | Newtown. | Newtown. |
| Codling Moth Infestation. | | Light. | Light. | Medium. |
| Number of Parasites Liberated. | | 8,000. | 8,000. | None. |
| Date of Liberation. | | July 9, 1929 | July 9, 1929 | ----- |
| Spread of Parasite Infestation. Spread in Feet. | Second Day. | 5 feet. | 5 feet | ----- |
| | Third Day. | 16 feet. | ----- | ----- |
| | Fourth Day. | 22 feet. | 11 feet | ----- |
| Spread to Other Trees. | | 3 adults on 2 trees. | No spread. | ----- |
| Check on Parasitism. | | | | |
| A. First Generation Codling Moth Parasitism. | No. of Codling Moth Eggs. | 13. | 4. | 7. |
| | No. of Eggs Parasitized. | 4. | 2. | 0. |
| B. Second Generation Codling Moth Parasitism. | No. of Codling Moth Eggs. | 9. | 6. | 7. |
| | No. of Eggs Parasitized. | 5. | 5. | 1. |
| Final Check on Parasitism Per Tree | No. of Wormy Apples. | 9. | 19. | 41. |
| | No. of Clean Apples. | 301. | 572. | 473. |
| | Per Cent of Wormy Apples. | 3% | 3% | 9% |
| Other Notes. | | A total of 46 codling moth eggs were counted for the three trees, 17 of which were parasitized, giving a percentage of 37, or less 3 per cent natural parasitism. 34. | | |

Second Control Experiment. (Table No. IV).

| Tree Numbers. | | 1. | 2. | 3. |
|---|---|---|---|---|
| Location. | | Central Orchard | Central Orchard | Central Orchard. |
| Variety. | | Newtown. | Newtown. | Newtown. |
| Codling Moth Infestation. | | Light. | Medium. | Medium. |
| Number of Parasites Liberated. | | 7,000. | 6,000. | None. |
| Date of Liberation. | | Aug. 7, 1929 | Aug. 7, 1929 | ----- |
| Spread of Parasite Infestation. | Second Day. | 2 feet | 9 feet | ----- |
| | Third Day. | 4 feet | 11 feet | ----- |
| Spread in Feet. | Fourth Day. | 10 feet | -------- | ----- |
| Spread to Other Trees. | | No spread | No spread | ----- |
| Check on Parasitism. | | | | |
| A. First Generation Codling Moth Parasitism. | No. of Codling Moth Eggs | ---------- | ---------- | ----- |
| | No. of Eggs Parasitized. | ---------- | ---------- | ----- |
| B. Second Generation Codling Moth. Parasitism. | No. of Codling Moth Eggs. | 6. | 13. | 10. |
| | No. of Eggs Parasitized. | 1. | 4. | 1. |
| Final Check on Parasitism Per Tree. | No. of Wormy Apples. | 12. | 16. | 39. |
| | No. of Clean Apples. | 412. | 390. | 561. |
| | Per Cent of Wormy Apples. | 3%. | 4%. | 7%. |
| Other Notes. | | A total of 29 codling moth eggs were counted for the three trees, 6 of which were parasitized, or 21%. | | |

Third Control Experiment. (Table No. V).

| Tree Numbers. | | 1. | 2. | 3. |
|---|---|---|---|---|
| Location. | | Benton's Orchard. | Benton's Orchard. | Benton's Orchard. |
| Variety. | | Delicious. | Newtown. | Newtown. |
| Codling Moth Infestation. | | Medium. | Medium. | Heavy. |
| Number of Parasites Liberated. | | 4,000. | 8,0000 | None. |
| Date of Liberation. | | Aug. 14, 1929 | Aug. 21, 1929 | ----- |
| Spread of Parasite Infestation. | Second Day. | ------------ | ------------ | ---------- |
| | Third Day. | ------------ | ~~5 feet~~ | ---------- |
| Spread in Feet. | Fourth Day. | 5 feet | 10 feet | ---------- |
| Spread to Other Trees. | | 11 adults on 2 trees. | 2 adults. | |
| Check on Parasitism. | | | | |
| A. First Generation Codling Moth Parasitism. | No. of Codling Moth Eggs. | ------------ | ------------ | --------- |
| | No. of Eggs Parasitized. | ------------ | ------------ | --------- |
| B. Second Generation Codling Moth Parasitism. | No. of Codling Moth Eggs. | 12. | 16. | 11. |
| | No. of Eggs Parasitized | 4. | 7. | 1. |
| Final Check on Parasitism Per Tree. | No. of Wormy Apples. | 39. | 47. | 41. |
| | No. of Clean Apples. | 465. | 588. | 229. |
| | Per Cent of Wormy Apples. | 8% | 8% | 18% |
| Other Notes. | | A total of 39 codling moth eggs were counted for the three trees, 12 of which were parasitized, or, 31%. | | |

The spread of parasites in feet was obtained by making careful observation as to the distance individuals had traveled from the cards during second, third, and fourth days following liberation.

The codling moth eggs counted in each control experiment for the check on parasitism did not comprise the total number of eggs per tree by any means, but they were all that could be found and counted in the allotted time.

An average of 29.6 per cent parasitism by _T. minutum_ was obtained for all eggs counted. Three per cent for parasites native to Hood River was deducted from this to give 26.6, the percentage of parasitism obtained from the introduced colonies. This, of course, includes the check trees. Liberation trees alone yielded a count of 81 codling moth eggs, 32 of which were parasitized, or 40 less 3 equals 37 per cent. This figure alone is fairly promising result, but it can be severely discounted by the poor dispersal of the parasite from one tree to another. Out of 41,000 parasites liberated on six different trees only 16 adults were ever found on adjacent trees. Eleven were found on two trees that were both on the windward side of a liberation tree, indicating the influence of prevailing winds.

The final check on parasitism by means of counts on numbers of wormy apples indicates, in the case of each experiment, the favorable influence of _T. minutum_, but it does not take into consideration the many outside factors that almost nullify the value of such figures. If the trees could have been caged in and factors eliminated such as codling moth adults from other trees and Trichogramma already present the counts would have been of much greater value.

Length of Trichogramma Generations at Hood River.

Fifteen parasitized codling moth eggs were kept under observation in the orchard during the months of July and August. Six of these were observed when a Trichogramma female oviposited. It was found that the average length of a generation in the field was 16 days, with a maximum of 21 days and a minimum of 12.

HISTOLOGICAL TECHNIQUE IN THE STUDY OF T. minutum.

On account of the small size of Trichogramma and the opaqueness of the Sitotroga host eggs microscopic examination of the various stages could not be made until specimens had been carefully mounted, usually in toto, on slides.

A total of 46 slides of T. minutum were made, Sections of the parasite within the host were mounted, but these did not prove very successful, chiefly owing to the hard chitenous covering of the Sitotroga eggs which rendered them most difficult to infiltrate, embed, and section. The few partially successful sections obtained were stained Heidenhain's iron-alum haematoxylin--eosin.

The most successful procedure for making slides of parasitized Sitotroga eggs in toto was as follows:

1. Kill and fix the material with boiling water, or Bouin's solution. Chromic-acetic-alcohol fixitive was not as successful as Bouins.

2. Place in 15, 30 and 50 per cent alcohol for 2 hours each.

3. Place in 70, 85, 95, and absolute alcohol for 4 hours each.

4. Place in cedarwood oil 50 per cent and absolute alcohol 50 per cent for 6 hours.

5. Clear in cedarwood oil for 8 to 12 hours.

6. Mount with Canada balsam. Use the following method for mounting adults: place the specimen on its back in a clean drop of water on a cover slip. Place the cover slip on a microscope slide. The wings, antennae and legs of the parasite are then spread in position under the binocular microscope. While still damp the specimen is brushed over with a thin solution of gum arabic and water. This dries fairly quickly and fixes the specimen to the cover slip. Touch the specimen with a small drop of balsam when it is

thoroughly dry. Place another drop of balsam on the slide. Turn the cover slip over with a pair of forceps and place it on the fresh drop of balsam. This presents the specimen with its back up.

Several mounts of the appendages of the adults were made, also of the predatory mite P. ventricosus.

SUMMARY***RECOMMENDATIONS.

The quantity production of T. minutum in the laboratories at Hood River and Corvallis has proved both feasable and practical, even with limited equipment. However, before large-scale daily production can be attempted certain important additions to rearing equipment would have to be made. A rearing room, about 12 by 14 feet--one that could be made air-tight for fumigation--with thermostatically-controlled temperature, would be a very necessary addition, but of course would be rather expensive. Bins, similar to those used by Hinds and Spencer (70), would be a necessary adjunct to the rearing room, to hold large amounts of corn and wheat for the raising of grain moths. A small cold storage plant--"Frigidaire" preferred--where variation of storage temperature could be easily secured, would be an even greater requisite than the rearing room. Additional egg-laying chambers and glassware would have to be added.

Only by the production of enormous numbers can Trichogramma be made a really effective agent in the control of codling moth in the Pacific Northwest. Because of its poor powers of dispersal from one tree to another liberations of many thousands would have to be made in almost every tree in an orchard. Thirty thousand parasites per tree per season would be a conservative estimate for effective control. Even then there is always the danger of great loss through changes to other hosts, and from cold wet springs. Then there is the mysterious loss in overwintering, part of which is due also to migration to other hosts.

Mass production at low cost may prove to be the deciding factor in the control of codling moth by the parasite. If one million Trichogramma per day could be raised for less than $10 the liberations could be made on such a large scale that even the drawbacks enumerated in the foregoing paragraph might be nullified, and a parasite superiority brought about which would help greatly to reduce the host to the point below the economic minimum.

## II. ASCOGASTER CARPOCAPSAE (Viereck).

### INTRODUCTORY REMARKS.

Ascogaster carpocapsae was first investigated as a parasite of the codling moth by the writer in the summer of 1926 at the Dominion entomological laboratory Vernon, B. C., Canada. It was not until the season of 1928 that any experiments with the insect were undertaken at the Oregon station.

In contrast to Trichogramma minutum little was known of the life history and habits of Ascogaster; it was a much more obscure parasite than the former. Greater emphasis, therefore, was placed on the study of the various habits and the stages in the life cycle of the insect.

No elaborate propogation methods for the rearing of Ascogaster carpocapsae in the laboratory have ever been undertaken. The parasite was not indigenous in the state of Washington or province of B. C. so it had to be introduced. E. J. Newcomer, senior entomologist of the U.S.D.A. has been the pioneer from this standpoint, just as has Stanley E. Flanders in the matter of rearing of large numbers of T. minutum.

Mr. Newcomer imported the parasite from the eastern states, about the year 1925, and has since bred up the stock to considerable numbers in the field. From a block of 58 trees about the original liberation point 22 per cent parasitism was obtained in 1926. This was increased to 31 per cent in 1927, for 7,700 codling moth larvae were found parasitized out of 24,800 larvae examined in the same block of 58 unsprayed trees. The parasite has been shipped to other parts of Washington, and to British Columbia. A slow but marked spread has been the result since the season of 1927.

The work at the Vernon and Corvallis laboratories comprised in the main, therefore, studies of the life history and habits of Ascogaster, liberations, orchard surveys, and a few experiments on commercial propogation.

DISTRIBUTION.

Ascogaster carpocapsae is, as nearly as can be ascertained, a native parasite of North America. It is indigenous in practically all of the north eastern and central United States. Unpublished records also show that it is also native in the states of Oregon and California. The only instance quoted which would seem to indicate the parasite is present in a natural state on other continents is that of Bragina (1), who claims to have bred Ascogaster from young codling moth larvae near Belgrade, Serbia. It seems doubtful if these were species of carpocapsae as they emerged from young codling moth larvae, which was never the case with any of the adults bred through by the writer, There might, of course, be a European strain, differing in parasitic habit.

HOSTS.

The difference in the number and variety of hosts between this parasite and T. minutum is very marked.

Apparently the insect is quite selective as to its hosts. It also exhibits a preference, favoring the codling moth quite distinctly. Hosts of Ascogaster are as follows:

ORDER LEPIDOPTERA.

Family Limacodidae.

1. Cnidocampa flavescens Wlk. Striped Peach Worm (22)

Family Gelechiidae.

1. Gelechia confusella Cham. (11) (13)

Family Eucosmidae.

1. Polychrosis viteana Clem. Grape Berry Moth. (12)
2. Carpocapsa pomonella L. Codling Moth. (Reared) (2) (9)
3. Laspeyresia molesta Busck Oriental Peach Moth. (3) (8) (18)

Only five known hosts, as compared to over 100 for T. minutum.

SYSTEMATIC CONSIDERATION.

Description and Synonomy.

The type locality of Ascogaster carpocapsae is Douglas, Mich. The original description, by H. L. Viereck, August, 1908, is as follows (20): "Chelonus carpocapsae, new species. This species is very like C. fissus, from which species as well as all other species of Chelonus it can readily be separated by the structure of the metathorax, which along the outer and upper edge of the posterior face is produced into four nearly equidistant prolongations that are nipple-shaped in outline, the productions nearest the middle line are farther from each other than from the outermost productions. This structure of the metathorax calls to mind the structure of the apical margin of the abdomen in Chrysis (Tetrachrysis) nitidula, though the productions are by no means thinned out or pointed in this case as in the foregoing species; scape and basal half of posterior tibiae mostly brownish, the apical half almost black.

Type--No. 12258, U. S. National Museum, Washington, D. C.

On authority of Mr. Braucher, working under the direction of Mr. Quaintance, the host of this species is the codling moth or Carpocapsa pomonella."

The original description is found in Viereck's article one "Descriptions of New Hymenoptera." Proceedings of the Entomological Society of Washington, volume XI, page 43.

Chelonus carpocapsae Viereck, embodying the original genus in which the parasite was described, is now a synonym, the species being more recently placed in the genus Ascogaster Wesmael. This is the only synonym.

Classification.

Ascogaster carpocapsae belongs to the order Hymenoptera, the suborder Clistogastra or Apocrita, which is distinguished as follows: the second abdominal segment, which appears as the first, is constructed to form a narrow petiole or waist between the large portion of the abdomen and the wingbearing region of the body. The family Braconidae belongs to this suborder. The distinguishing characteristics of the family are as follows: a large family with specimens of small or moderate size; the costal cell of the fore wings has been eliminated by the coalescence of veins. The venter is membfanous and has in dried specimens a longitudinal fold; the vein between cell M1 and cell 1st M2 is wanting (Pl. IX ). The genus Ascogaster is distinguished by having the clypeus not emarginate; the abdomen concave beneath, and with only one segment visible above; the fore wings with three submarginal cells; the eyes bare.

In America only a small number of species make up the genus Ascogaster: A. provancheri Dalla Torre (21), A. flaviceps Ash. (21), A. provancheri var. pallidicornis Vier. (21), A. carpocapsae (Vier.) (21), A. olethreuti Vier. (21), A. aughei La Mun, (5) A. nebraskaensis La Mun (5), A. rufipes Prov. (5). Eight species in all, with one variety. The following are evidently European species: A. annularis, A. quadridentatus, A. canifrons, and A. rufidens.

ADAPTABILITY TO CONTROL OF CODLING MOTH.

From the standpoint of the conventional insect parasite A. carpocapsae appears to be much more a promising species than T. minutum. A few of its advantages as a codling moth parasite may be enumerated as follows:

1. It mates and oviposits readily in confinement.

2. It has a limited host range, and a preference for the codling moth.

3. It has no alternate host, and will develop throughout the year in the codling moth.

4. Its powers of dispersal are good--much better than Trichogramma.

5. It has an equal development range with its host.

6. It accomodates itself to the codling moth generations according to the locality.

7. It is fairly free from hyperparasites and predaceous insects.

8. It is capable of outnumbering its host in the field.

9. Adults will live for over a week and continue to oviposit throughout most of their life.

Factors which limit the usefulness of *Ascogaster* are:

1. It is very hard to raise in large numbers in the laboratory owing to lack of a suitable laboratory host.

2. It does not kill the host before it hatches as does *Trichogramma*.

3. It has a rather serious hyperparasite -- *Dibrachys boucheanus* (Ratz.).

4. Where sprays are applied for the control of the host the parasite is subject to the same mortality as the host owing to its long period of development within the tissues of the latter.

5. It is prey for birds and insect predators which attack its host.

6. It is subject to superparasitism by *Calliephialtes messor* Grav., also by other specimens of its own species.

LIFE HISTORY AND HABITS OF *A. carpocapsae*.

This insect is an example of a parasite that lives for a long period of time within the host and destroys very few of its tissues. This is an uncommon occurrence within the field of insect parasitism.

Mating and Oviposition.

The adult parasites are restless nervous insects, and they exhibit sexual interest as soon as they are able to fly, especially if they are placed in sunlight. They mate readily, either in confinement or in the orchard. Copulation last about one minute, and the positions assumed by male and female in the act are normal for insects. Females have remained gravid and have continued to deposit eggs for 10 days in the laboratory.

Owing to lack of knowledge as to which stage of the codling moth that was attacked by the parasite oviposition was at first not observed in the laboratory. Larvae, pupae, and eggs of the codling moth, also an egg mass of Archips cerasiforana (Fitch) were placed with the parasites in the rearing tubes, but little interest was at first manifested by the adults. A day later two females and two males of Ascogaster were placed in a vial containing 14 codling moth eggs, laid on the glass. After about five minutes the females discovered the eggs, and immediately began to feel and pat them with their antennae. They next stood astridedof them while they punctured the chorion with a slight drilling motion, discernible in the movement of the abdomen. Actual oviposition only lasted about 20 seconds. The parasites were removed after 20 minutes, and they were still ovipositing at time of removal.

Three days later a female from one of the feeding tubes was confined for 2½ hours in a small vial within which was a pear leaf containing nine eggs of C. pomonella. From a fairly constant observation it was noted that every host egg was parasitized, some more than once.

Four females, from one of the battery jar cages, were placed separately in small vials, within which were small portions of apple leaves, each containing from two to eight codling moth eggs. Oviposition in each vial was quite rapid and apparently very thorough.

The parasite egg hatches four to six days after the hatching of the codling moth egg.

B. G. Thompson, of the Oregon Experiment Station (Unpublished. Notes cannot be located) claims to have observed Ascogaster in the act of depositing eggs on the outside of the host egg, and in its immediate vicinity. This ectodeposition is characteristic of many Braconids, but nevertheless Thompson's observations are contrary to the findings of Newcomer (unpublished), Cushman (24) and the writer, who have all observed the parasite egg to be deposited inside the chorion of the host egg. This point is one that demands further investigation.

Emergence of Larvae.

Larvae of A. carpocapsae commence to emerge from the overwintering and second brood codling moth larvae a little before the emergence of moths. The caudal end of the parasite breaks through the epidermis of the host at a middle ventral segment of the abdomen, and then emerges very slowly. When about half the larva has come out the caudal end is often pressed against the side of the worm to assist the former in freeing itself more quickly. The parasite larva takes from 20 minutes to one hour to completely free itself from the host. (Pl. X)

Description of Larva.

The mature parasite larva, on emergence, is a light cream color, very shiny; average length 5mm. (Pl.X); head very indistinct, but with mouth parts visible; a grub otherwise devoid of all appendages.

Condition of the Host on Emergence of the Parasite.

The parasitized host larvae are about two-thirds grown at the stage of parasite emergence, and are in cocoons. They are in a very shrivelled condition, and their color is darker than the average. The codling moth larvae do not die until the parasite commences to emerge. In fact some worms showed signs of life when the parasite larvae were over half way out.

The parasitized larvae exhibit their stunted condition when they emerge from fruit. A measurement of 20 head capsules of full-grown codling moth worms, half of which were parasitized, showed an average size of 1.6 mm. for the normal larvae, and 1.3 mm. for the parasitized larvae. Observations check with an experiment performed by Hammar (10) in 1912.

Pupal Stage.

The larva of A. carpocapsae spins a cocoon and pupates as soon as it emerges from the host.

The cocoon of the parasite is formed inside the old cocoon of the codling moth. Five days after emergence of the larva the cocoon appears as a slightly transparent and snow white cylindrical object; except for several hollows and ridges, rounded at each end. There is a distinct lustre to the cocoon. The numerous threads are closely matted together and there are few stray or attachment threads. The head of the pupa shows through the cocoon as a light brown mass.

Adult Stage.

The adult emerges 10 to 15 days after pupation. It pushes out from the cephalic end of the cocoon, tearing loose a circular piece of the latter which usually remains hinged to the rest of the cocoon by several silken threads. (Pl. X-4)

Habits of Adults.

The adult parasites are very active nervous insects. In all their life processes this activity is continually exhibited. Whenever a shipment of adults is liberated in an orchard the females begin at once to hunt diligently for eggs of the codling moth, flying from one leaf to another, crawling all over the leaf and feeling its surface with their ovipositor.

Adults fed freely in captivity in the laboratory. During the first season a large series was fed on a 50-50 honey and water mixture, drops of which were placed on a wax smear inside long glass vials. The next season a new feeding mixture was tried, made up of the following:

| | |
|---|---|
| Cane sugar................ | 2 oz. |
| Amyl acetate.............. | 3 cc. |
| Water..................... | 78 cc. |
| Ethyl alcohol (100%)..... | 20 cc. |

The sugar was dissolved in the water, which was heated, and the amyl acetate and alcohol were then added. When cool a drop of this mixture was placed on a wax smear on a glass slide. The slide was cemented to a glass stand in a large feeding jar (battery jar), which contained, on the average, 20 adult parasites. After a thorough trial it was found that the foregoing feeding mixture kept better than the honey and water mixture, but otherwise had few advantages.

The life of the adults of A. carpocapsae averaged from eight to ten days in the laboratory without food, and two to three weeks with food.

Hyperparasitism.

Care was taken to breed out all material received from Mr. Newcomer at Vernon, Corvallis, and Hood River, to the adult stage before any liberations were made. This care was rewarded when three lots of hyperparasites were reared on different occasions. These were determined by A. B. Gahan, U. S. Bureau of Entomology, as Dibrachys boucheanus (Ratz.). All hyperparasites have been destroyed as soon as they emerge. These precautions may be futile as the species is probably indigenous.

COMMERCIAL REARING OF A. carpocapsae.

Commercial rearing, if it could be called by that term, was undertaken to obtain a greater number of parasites from the original imported stock secured from Mr. Newcomer, and to increase the number of overwintering larvae.

Materials and methods were simple, most of them already having been referred to.

The corrugated cardboard, containing the puparia of the parasite, was cut up into small strips, each containing about five pupae. About 12 of these strips were placed on the floor of a tightly-fitting wooden box cage, 6 by 5 by 3 inches in size, with holes bored to receive emergence vials. The emerging adults, being positively phototropic, flew or crawled into the vials.

The adults were transferred from the emergence vials to 10 inch battery jar cages. These had a layer of moist sand on the bottom, a feeding stand (previously described), and a wire screen top held on with a special clamp.

Codling moth eggs, on foliage or fruit, were placed with the adults in the battery jar cages. Oviposition took place quite readily. The parasitized eggs were then placed in other battery jars with apples, and the life cycle of the codling moth allowed to continue until emergence of the parasite.

LIBERATION OF PARASITES.

Liberations of A. carpocapsae were made at Vernon, Kelowna, and Cranbrook, B. C., and at Hood River, Ore.

The first liberation was made at Kelowna, June 14, 1927, when 35 adults were let loose. A second liberation was made at Kelowna in August of the same year when 100 parasites were set free.

Thirty adults were liberated at Vernon in August, 1927.

A shipment of parasitized codling moth larvae, reared in the laboratory, was sent to A. A. Dennys, junior entomologist of the Dominion government, at Cranbrook. Mr. Dennys bred through and liberated 60 adults of A. carpocapsae from the shipment.

Sixty-five parasites were liberated at Hood River in June, 1929.

SUMMARY****RECOMMENDATIONS.

*Ascogaster carpocapsae*, as a codling moth parasite, has two advantages over *T. minutum* that, in the writer's estimation, place it above the latter from the standpoint of potential biological control, namely its narrow host range and preference for the codling moth, and its power of dispersal. A third, though less marked advantage is its safe, more stable overwintering habit--within the cocoon-protected larva of the codling moth.

At present there is not much promise for the parasite from the standpoint of commercial propogation until a more suitable laboratory host has been discovered, and the technique of rearing large number of the parasite in the laboratory has been perfected.

The keynote for future work with *A. carpocapsae* then is investigation of a method to raise it in large numbers. Additional and more intensive field surveys of the natural occurrence of the parasite, its dispersal, and its percent of codling moth parasitism are also required.

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Table given showing colonization data and results. Nearly 100 per cent parasitism by late autumn

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Prospects of Controlling the Sugar Cane Borer Efficiently. La. Planter, Dec. 20, page 416.
Non-burning of trash in fields to control the borer. Control depends on presence of Trichogramma. Parasite common in La. and Texas.

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Parasite Intro. as a Means of Saving Sugar. Jnl. Ec. Ent., vol. 12, pages 176-178.
Holloway ships Trix, along with 4 other parasites, from Cuba to New Orleans. Methods of collecting and shipping. Sugar leaves no longer burned but plowed under later, thus allowing Trix to emerge from eggs on the leaves.

77. Holloway, T. E. 1921.

European Corn Borer and Sugar Cane Moth Borer: a Comparison. Jnl. Ec. Ent. Vol. 14, page 485.
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T. minutum, according to Marlatt. 100% of sugar cane moth borer are parasitized late in fall; too late for effectual control.

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Insects Attacking Sugar Cane in U. S. Jnl. of Ec. Ent., Vol. 12, page 448. Diatraea saccharalis.

79. Holloway and Loftin. 1919.

The Sugar Cane Moth Borer. U.S.D.A. bull. 746, pages 39-41.

Trix universally distributed in La. and Texas, and an important control factor. Parasites scarce in early part of season. Become more and more abundant as season progresses. Description of adults given Low temp. retards development. All died when kept in a refrigerator over winter at 50 degrees F. Some emerged at this temp. Trix hibernates in cane trash over winter.

Trix occurs in Cuba, Porto Rico, Trinidad, Br. Guiana, Barbados, Java, and elswhere.

Drawings of Trichogramma accompany article.

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Importation into U. S. of Parasites of the Gypsy Moth. U.S.D.A. Bureau of Ent. bull. 91, page 257.

Ten adult parasites bred from one brown tail moth egg. Life cycle varies from 9 days to 3 weeks according to temp. Development of parasites within host eggs may be delayed several weeks--even months, even with high temperatures. Parthenogenesis: Am. form produces all males; European form: all females or both male and female. Parasites kept in cold storage through winters of 1908 and 1909 and many thousands liberated. Trichogramma was not a successful parasite of the browntail moth as it is physically unable to pierce many browntail moth eggs.

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Trix mentioned as parasite of European rose slug, Caliroa aethiops, Fabr. in Kan. 25% parasitism. One to three flies from each egg. Method and time of emergence given.

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Mentioned as a parasite of the grape berry moth (Polychrosis viteana).

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Native parasitism practically negligible except in case of the sporadic T. minutum which fluctuates greatly from year to year. Highest parasitism too late in season except when a cold dry summer delays host. 61% par. in second generation.

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Insects Affecting Vegetables in Porto Rico. U.S.D.A. bull. 192, page 7.

Trix mentioned as parasitizing eggs of the bean leaf roller, Gonius proteus, L.

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The Codling Moth in the Santa Clara Valley. U.S.D.A. Bureau of Ent. bull. 115, page 160.
Table of the life cycle of Trix in codling moth eggs. Av. life cycle was 24.06 days in the field, but this is calculated from the time the codling moth eggs were laid.

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Caterpillars Which Eaat the Leaves of Sugar Cane in Porto Rico. Jnl. Dept. Ag. and Labor of Porto Rico. Vol. 6, no. 1; page 41.
The skipper Prenes nero Fab. kept down by T. minutum. Seven to eleven adults often emerge from a single egg.

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Le "ver" de la Canne a Sucre aux Antilles Francaises (D. saccharalis). Rev. Bot. appl., VIII, no. 87, pages 755-767. Paris.
T. minutum the most important parasite of D. saccharalis in the Guadeloupe.

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95. List, Daniels, and Bjurman 1928.

Sulphur in the Control of Mites in Parasite Breeding Laboratories. Jnl. Ec. Ent., vol. 21, no. 6, page 940. Geneva, N. Y.

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Trichogramma listed as a parasite of the army worm Laphygma frugiperda.

98. Marchal, P. 1927.

Contribution a L'etude Genotypique et Phenotypique des Trichogrammes. C. R. Acad. Sci. France CIXXXV no. 9, pages 489 to 493.

T. minutum not considered but T. evanescens and T. cacoecia n. sp. are genetically and specifically distinct. He suggests that a number of strains from different parts of the country may be found in any species of Trichogramma, the formation of which has been helped by thelyotokous parthenogenesis. T. cacoecia has only two generations per year in Tortrix rosana, the first generation being wingless. Reproduction is entirely parthenogenetic. The number of generations is increased when this species attacks Barathra brassicae. Development is evidently regulated by the host.

99. Marlatt, C. L. 1928.

Report of the Entomologist. U.S.D.A. 1928, Washington.

T. minutum which attack the eggs of Cydia molesta, was found to have at least 13 generations during the season. Life cycle of 8 days at 80 degrees F. and 50-65 days at 50 degrees.

100. Martin, C. H. 1928.

Biological Studies of Two Parasites of Aquatic Insects. Entomologica Americana, vol. 8, no. 3 (Dec. 1927) page 105-156.
Detailed life history of Trichogramma, number of hosts, lists of hosts, new host records, parthenogenesis, oviposition, etc.

101. Marshall, J. 1927.

Larval Mortality of the European Corn Borer in 1926. 56th Annual Repost of the Entomological Soc. Ont. page 34.
Some Trichogramma parasitism of corn borers in 1925 but none in 1926. No reason given.

102. Mc Connell, H. S. 1928.

The Oriental Fruit Moth. Maryland Ag. Exp. St. bull. 298, page 179-180.
An important egg parasite, especially late in the season.

103. Mokrzecki S. A. 1913.

Report on Injurious Insects and Diseases of Plants in the Government of Taurida During the Year 1912. Simferopol, pages 1 to 23.

104. Mokrecki and Bragina. 1916.

The Rearing of T. semblidis and T. fasciatum in the Laboratory and Temperature Experiments on them. Salgir Exp. Pomological Station, Simferopol (Crimea).

105. Morrill 1914.

Pests of Vegetable Crops. Arizona Comm. of Agri. and Hort. Rept. 6, page 40.
Trix parasitized 38 per cent of the eggs of the cotton boll worm, Alabama argillacea in Ariz.

106. Newcomer, E. J. 1916.

The Dock Falseworm: an Apple Pest. U.S.D.A. bull. 265, page 34.
A total of 268 eggs of Ametastigia glabrata, counted at Wenatchee, yielded 11.9% parasitism, from July 2 to Sept. 8.

107. Newcomer and Whitcomb. 1925.

Life History of the Codling Moth in the Yakima Valley. U.S.D.A. bull. 1235, page 72.
Mentioned as a parasite of Cydia pomonella at Yakima.

108. Parrot and Fulton. 1915.

Cherry and Hawthorne Sawfly Miner. Jnl. of Ag. Research. Vol. 5, page 526.
Large percentage of leaf miners attacked by Trix in 1912. 40% to 90% parasitism in 1915. Eggs dissected. Parasites in larval state June 2, pupa June 6, first adult June 9, last adult June 14.

109. Parrott and Harman. 1929.

The Bud Moth. Circ. N. Y. Ag. Exp. St., no. 109, 10 pages.
Mentioned as the most abundant parasite of Tmetocera ocellana.

110. Peterson, A. 1926.

Baits Attractive to the Oriental Peach Moth. Jnl. of Ec. Ent. vol. 19, page 433.
Trichogramma abundant as a par. in N. J. in Aug. and Sept. 2 to 20 per cent infestation.

111. Phillips and King. 1923.

The Corn Earworm. U.S.D.A. BUll. (Farmer's) 1310, page 11.
Trix attacks many of the corn earworm eggs, especially those on leaves. Not dependable. Some years almost 100 per cent parasitism.

112. Peterson, A. 1926.

Additional Information on Baits Attractive to the Oriental Peach Moth. Jnl. Ec. Ent. vol. 19, no. 3, page 435.
Trichogramma parasitism found to be as high as 60 per cent for the peach moth in late summer.

113. Phillips, Underhill, and Poos. 1921.

The Larger Corn Stalk Borer. Virg. Tech. bull. 22, page 15.

T. minutum reported as by far the most common parasite of the stalk borer in N. Carolina in 1920.

114. Portchinsky, I. A. 1913.

Phalera bucephala L. and its Importance for the Artificial Breeding of Pentarthron semblidis in Winter. Memoirs Bur. Ent. Science Committee. Central Bd. of Land Admin. and Agr. Vol. 10, pages 1 to 16, illustrated. (Russian).

115. Quaintance, A. L. 1907.

The Codling Moth or Apple Worm. U. S. Year Book for 1907, page 443.
Mentioned as a parasite of the codling moth--3 to 4 per egg.

117. Quayle, H. J. 1926.

The Codling Moth in Walnuts. Cal. Ag. Exp. St. Bull. 402, 33 pages.
Mentioned as parasite of the codling moth.

118. Radetsky, A. F. 1913.

Orphthora semblidis, Description, Biology, and Utilization of it in the Struggle with C. pomonella L. Turkestan Ent. Station Tashkent. 28 pages (Russian).

119. Reed. 1909.

The Codling Moth in Georgia. Georgia Bd. of Ent. bull. 29, page 19.
The most beneficial egg parasite. Parasitism was 19 per cent for the second brood. Five adults were bred from one codling moth egg. Adults may or may not emerge from separate exit holes.

120. Riley, C. V. 1871.

Third Report. Record of American Entomology, page 158.
This contains the original description of T. minutum.

121. Riley, C. V. 1871.

Record of Entomology, page 8.
Generic name Pentarthron proposed for T. minutum, but it had to be changed as the name had been used before by Wollaston.

122. Riley, C. V. 1881.

Descriptions of New Species and Varieties. General Index and Supplement to the Ninth Report on the Insects of Missouri. U.S.D.A. bull. no. 6, page 68.
The second description of T. minutum.

123. Riley, C. V. 1882.

Efficacy of Chalcid Egg Parasites. American Naturalist, Vol. 16, pages 914 to 916.

124. Russell, H. M. 1913.

Egg Parasites of Datana intergerrima. Proc. of the Ent. Soc. of Wash. vol. 15, page 91.
From 7,187 eggs of Datana only 2.1 per cent parasitism was obtained by Trichogramma, as against 65 per cent by Telenomus sphingis. Four and five Trichogramma observed emerging from one egg.

125. Sherman and Leidy. 1920.

The Green Clover Worm as a Pest of Soy Beans. N. Carolina Ext. circular 105, page 7.
T. minutum (pretiosa) as par. of this moth. Three adults have emerged from one egg.

126. Smith, H. S. 1915.

Insect Notes. Cal. Hort. bull. 7, page 345.
Mentioned as a reared parasite of codling moth.

127. Taylor, E. P. 1906.

Report of the Field Entomologist. Col. Report 19, page 149.
Mentioned (called a microscopic bee) as a parasite of the codling moth.

128. Severin, H. C. M. and H. H. P. 1908.

Habits of the American Sawfly Cimbex americana Leach with Observations on its Egg Parasite

Trichogramma pretiosa. Trans. Wis. Acad. Science Arts and Letters. Vol. 16, pages 61 to 76.

129. Smith, R. C. 1924.

Caenurgia erechtea (Noctuidae) as an Alfalfa Pest in Kansas. Jnl. of Ec. Ent. vol. 17, no. 2, pages 312 to 319.

Trichogramma mentioned as parasite under laboratory conditions of the eggs of the forage looper (C. erechtea).

130. Swezey, O. H. 1928.

Entomology. Rept. Commercial Exp. Sta. of Hawaiian Sugar Planters Assn. 1926-27, pages 15-27.

T. minutum occasionally reared from eggs of Spodoptera mauritia, the nut-grass army worm.

131. Taylor, E. P. 1906.

Western Slope Fruit Investigations, 1906. Colorado bull. 119, page 4.

Mentioned as a parasite of codling moth.

132.m Townsend, C. H. T. 1928.

Insectos que Atacan al Algodon y a la Cana de Azucar en el Peru. Bol. Extac. exper. agric. Soc. nac. agrar., no. 1, page 26.

Mentioned as an abundant parasite of D. saccharalis in Peru.

133. Tucker, R. W. E. 1929.

Sugar-cane Borers. Trop. Ag. vol. 6, no. 8, pages 224-226. Trinidad.

Destroys 90 per cent of the eggs of D. saccharalis at the end of the season and then maintains itself in small numbers mainly in the eggs of Utetheisa ornatrix L. Commercial propogation has been undertaken. The method is described.

134. Veitch, R. 1928.

Report of the Chief Entomologist. Brisbane, Queensland Dept. of Ag. 1927-28.

Colony of Trichogramma received from U. S. reared from eggs of Ephestia sp. and liberated but no evidence has been found regarding its control of the codling moth.

135. Viereck, H. L. 1916.

Hymenoptera of Connecticut. State Geological and Natural History Survey Bull. no. 22, page 445.
Systematic consideration of family, genera, and species.

136. Voelkel, Herman 1925.

Uber die Praktische Bedeutung der Schlupfwespe _Trichogramma evanescens_ Westw. Arbeiten aus der _Biologischen Reichsanstalt fur Landund Forstwirtschaft._ Vierzehnter Band, Heft 2, pages 97 to 108. Berlin.
A parasitism of _Pieris brassicae_, L., _P. napi_ L., and _Barathra brassicae_, L., amounting to 78 to 100 per cent in the sun, and 38 to 55 per cent in the shade, near Berlin. _T. evanescens_ showed a marked preference for light. Drawings, tables.

137. Vuilett, A. 1927.

Utilization of Certain Phytophagous Insects in Combating Pests of Cultivated Plants. Revue Scientifique, Paris, 1927, pages 526 to 530.

138. Wildermuth, V. L. 1914.

The Alfalfa Caterpillar. U.S.D.A. bull. 124, page 19.
26 eggs of _Eurymus_ produced 76 _Trichogramma_ adults. Two broods of parasites on the eggs of one generation of _Eurymus_. Drawing of _T. minutum_ ovipositing. Other parasites and predators listed and discussed.

139. Wildermuth, V. L. 1920.

The Alfalfa Caterpillar. U.S.D.A. Farmers' bull. 1094, page 8.
Trix mentioned as often destroying 50% of the eggs of _Eurymus_.

140. Wishart, G. 1929.

Large Scale Production of the Egg Parasitized _Trichogramma minutum_. Can. Ent. vol. IXI, no. 4, pages 73-76. 5 figs.
Method employed much the same as Flanders, except that heat has to be employed to keep the grain moth alive.

141. Wishart, G. 1929.

Note on the Rearing of Trichogramma minutum. Sci. Aggic., vol. 9, pages 616-617. Ottawa.

By keeping the parasitized grain moth eggs in the dark and then placing them in bright light they all emerged within 24 hours, and parasitism was short and complete, thus eliminating most of the waste of both parasites and grain moths.

142. Wolcott, G. N. 1915.

Diatraea saccharalis. Jnl. of Ec. Ent. vol. 8, page 497.

Abundance of Diatraea depends upon scarcity of Trichogramma. Burning of cane tops in Texas and La. destroys the parasite.

143. Wolcott, G. N. 1918.

An Emergence Response of Trichogramma to Light. Jnl. of Ec. Ent. vol. 11, page 205.

1,506 clusters of D. saccharalis eggs collected, 63 per cent being parasitized by T. minutum. Eggs still black after emergence, because of black debris. Normal time of emergence is 2 hours after sunrise. Emergence delayed by keeping parasite eggs in dark. Six times as many adults of Trichogramma.

144. Wolcott, G. N. 1922.

The Sugar Cane Borer. Porto Rico Dept. Ag. and Labor Jnl. #6; pages 22 to 24.

Large Drawing of adult, page 2?. Parasitism of D. saccharalis. Where sugar cane trash is burned many hibernating adult Trichogramma and the next year there is a heavy borer infestation.

145. Wood, W. B. 1918.

The Oriental Peach Moth. Cal. Hort. bull. 7, page 527.

Mentioned as parasite of the peach moth.

146. Zweluwenburg Van, R. H. 1926.

Insect Enemies of Sugar Cane. Jnl. of Economic Ent. vol. 19, page 667.

Trichogramma mentioned as heavy parasite of Diatraea saccharalis. Last generation of the season

resulted in parasitism as high as 70 per cent.

147. Zwaluwenburg, Van, Rust, and Rosa. 1928.

Notes on the Rice Borer, Chilo simplex. Hawaii. For. and Agric. vol. 25, no. 3, page 81. Honolulu.
Mentioned as a parasite of the rice borer.

148. ---------------- 1910.

A New Foe For the Codling Moth. Better Fruit, for Oct. 1910, page 53.
Trix found parasitizing the codling moth in Colorado. Especially beneficial in the second generation. (Popular).

149. Zorin, P. V. 1927.

A Method of Rearing Trichogramma evanescens Westw. Defense des Plantes. Vol. 4, pages 316 to 319 (Leningrad). (Russian).

## FOR ASCOGASTER CARPOCAPSAE (Viereck).

1. Bragina, A. 1926.

Parasites of Cydia pomonella, L., In Belgrade (Serbian). Glasnik Centralnog Higijensk. Zavoda, vl.1. pt. 1 to 3, page 61. Belgrade.
Ascogaster bred from young larvae of codling moth.

2. Bourne and Whitcomb. 1927.

The Codling Moth in Massachusetts. Bull. Mass. Ag. Exp. Sta., no. 233, page 60.
Ascogaster mentioned as parasite of the codling moth.

3. Britton, W. E. 1919.

Eighteenth Report of the State Entomologist. Conn. bull. no. 211, page 303.

Ascogaster mentioned as a parasite of the oriental peach moth, Laspeyresia molesta Busck.

4. Brooks and Blakeslee. 1915.

Studies of the Codling Moth in the Central Appalachian Region. U.S.D.A. bull. no. 189, page 46.
Ascogaster the most numberous codling moth parasite in the Appalachian regions. Lateral view photo of adult which cannot be A. carpocapsae.

5. Cresson, E. T. 1887.

Synopsis of the Families and Genera of the Hymenoptera of America, North of Mexico. Trans. Am. Ent. Soc. Supp. volume, 1887, pages 59, 138, 225.
Systematic consideration of the genus Ascogaster, and species other then A. carpocapsae.

6. Cushman, R. A. 1913.

The Calliephialtes Parasite of the Codling Moth, Jnl. Ag. Res. vol. 1, no. 3, page 235.
Codling moth larvae containing larvae of Ascogaster were attacked and by Calliephialtes larvae, resulting in the death of the former.

7. Dozier, H. L. 1926.

Department of Entomology. Del. Ag. Exp. St. bull. no. 147, page 19.
Ascogaster the most abundant codling moth parasite in Delaware.

8. Garman, P. 1918.

A Comparison of the Several Species of Lepidoptera Infesting Peach and Apple in Maryland. Md. bull. no. 223, page 117.
Ascogaster listed as a parasite of the oriental peach moth. D. boucheamus (Ratz.) apparently a hyperparasite (no definite statement).

9. Hammar, A. G. 1910.

Life History of the Codling Moth in Northwestern Pennsylvania. U.S.D.A.B. Ent. bull. no. 80, part 6, page 110.
Ascogaster issued from band material of two broods and was quite common.

10. Hammar, A. G. 1912.

Life History Studies of the Codling Moth in Mich. U.S.D.A.B. Ent. bull. no. 115, part 1, pages 6 and 74.
6.58 per cent of larvae parasitized by Ascogaster. They are seldom more than half grown and lack pink color of healthy larvae.
Mentioned as native; synonym given; illustrations; states in which it is found; percentage of parasitism.

11. Ingerson, H. G. 1918.

The Striped Peach Worm. U.S.D.A. bull. no. 599, page 12.
Ascogaster reared from Gelechia confusella. Cham.

12. Johnson and Hammar. 1912.

The Grape Berry Moth. U.S.D.A.B. Ent. bull. no. 116, part 2, page 48.
Parasitic on eggs of Polycrosis viteana Clem. Adults emerged from pupae Aug. 1911.

13. Leonard, M. D. 1926.

A List of the Insects of New York. Cornell Ag. Exp. St. Memoir no. 101, page 903.
"A widely distributed parasite of the larva of the codling moth"......It is also recorded as reared from Gelechia confusella Cham.

14. Newcomer, E. J. 1928.

The Codling Moth Parasite, Ascogaster carpocapsae. Jnl. Ec. Ent. vol. 21, no. 1, page 221.
7,700 codling moth larvae parasitized out of 24,800 examined in a block of 58 unsprayed trees, or 31 per cent. 22 per cent parasitism in 1926. Approx. 1,300 shipped to B. C.

15. Petit, R. H. 1926.

Report of the Section of Entomology. Sixty-fourth Ann. Rept. St. Bd. Agr. of Mich. for 1924-25.
Ascogaster a real factor in control of codling moth.

16. Selkregg and Siegler, 1928.

Life History of the Codling Moth in Delaware. U.S.D.A. Tech bull. no. 42, page 52.
Ascogaster the most prevalent codling moth parasite.

17. Siegler and Simanton. 1915.

Life History of the Codling Moth in Maine. U.S.D.A. bull. no. 252, page 48.
Ascogaster frequently reared as par. of the codling moth.

18. Stearns, L. A. 1927.

A Report of the Investigation of the Oriental Peach Moth (Laspeyresia molesta Busck.) for 1925-26. Rept. N. J. Ag. Exp. Sta. 1925-26, page 192.
Mentioned as a parasite of the oriental peach moth.

19. Van Leeuwen, E. R. 1929.

Life History of the Codling Moth in Northern Georgia. U.S.D.A. Tech. bull. no. 90, page 78.
Parasitism of codling moth by Ascogaster was about 7 per cent.

20. Viereck, H. L. 1909.

Descriptions of New Hymenoptera. Proc. Ent. Soc. Wash., vol. 11, page 43.
The original description of Ascogaster carpocapsae.

21. Viereck, H. L. 1916.

Hymenoptera of Connecticut. State Geological and Natural History Survey. Bull. no. 22, pages 218, 231.
Key to species and description.

22. Wilcox, A. M. 1918.

Ascogaster carpocapsae, a Parasite of the Oriental Moth. Psyche, vol. 25, page 17.
Parasitic on Cnidocampa flavescens Walk. A description from other species given.

23. Wood, W. B. 1918.

The Oriental Peach Moth. Cal. Hort. bull. 7, page 527.
Mentioned as parasite of the peach moth.

24. Wood and Selkregg. 1918.

Further Notes on Laspeyresia molesta Busck. Jnl. Ag. Res. vol. 13, no. 1, page 70.
Ascogaster a parasite. Oviposits in the egg of the oriental fruit moth, and kills it in the larval stage after it has spun its cocoon.

25. Dozier and Butler 1929.

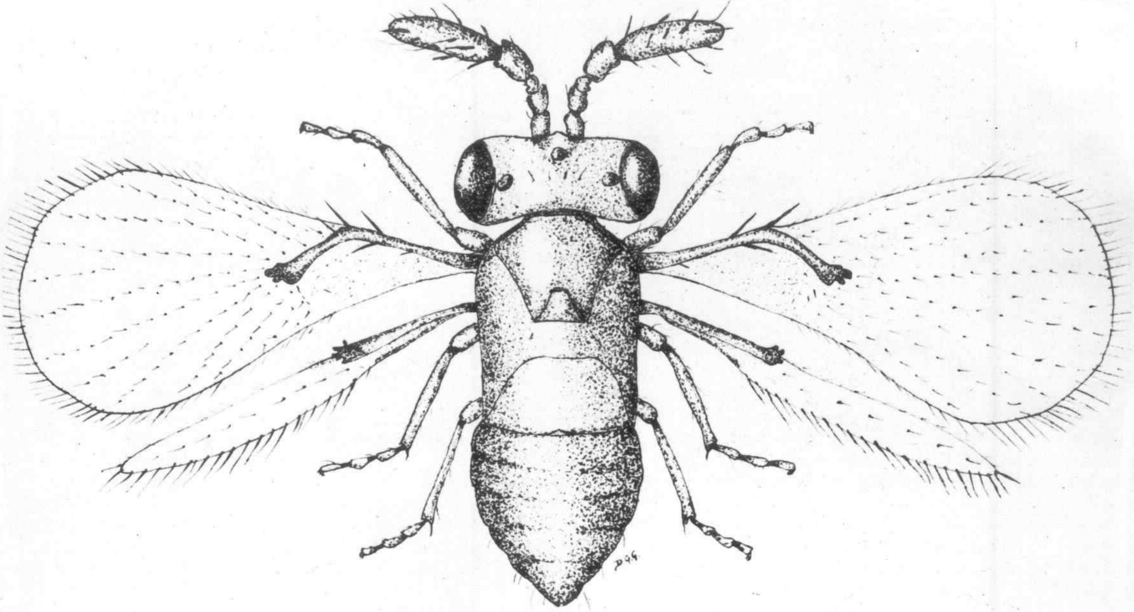
Notes on the Rearing of A. carpocapsae a Braconid Parasite of the Cødling Moth. Jnl. Ec. Ent. Vol. 22, No. 6, Dec., page 954.
Record of incubation period, length of larval feeding period, length of period elapsing from the time the codling moth larva left the fruit until emergence of the adult of parasitized codling moth larvae.

PLATE I

Fig. 1. Adult of *Trichogramma minutum* Riley, enlarged 245 times.

Fig. 2. Brachypterous adult of *T. minutum*, enlarged 245 times. A-1 and A-2 are wing stubs.

PLATE I



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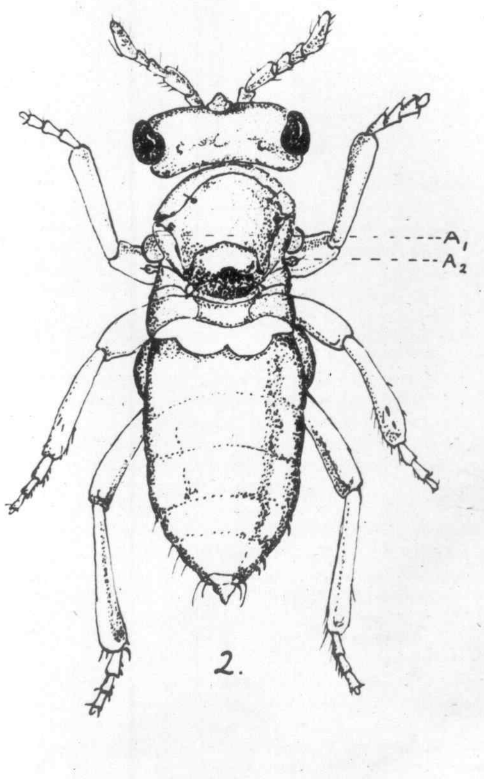


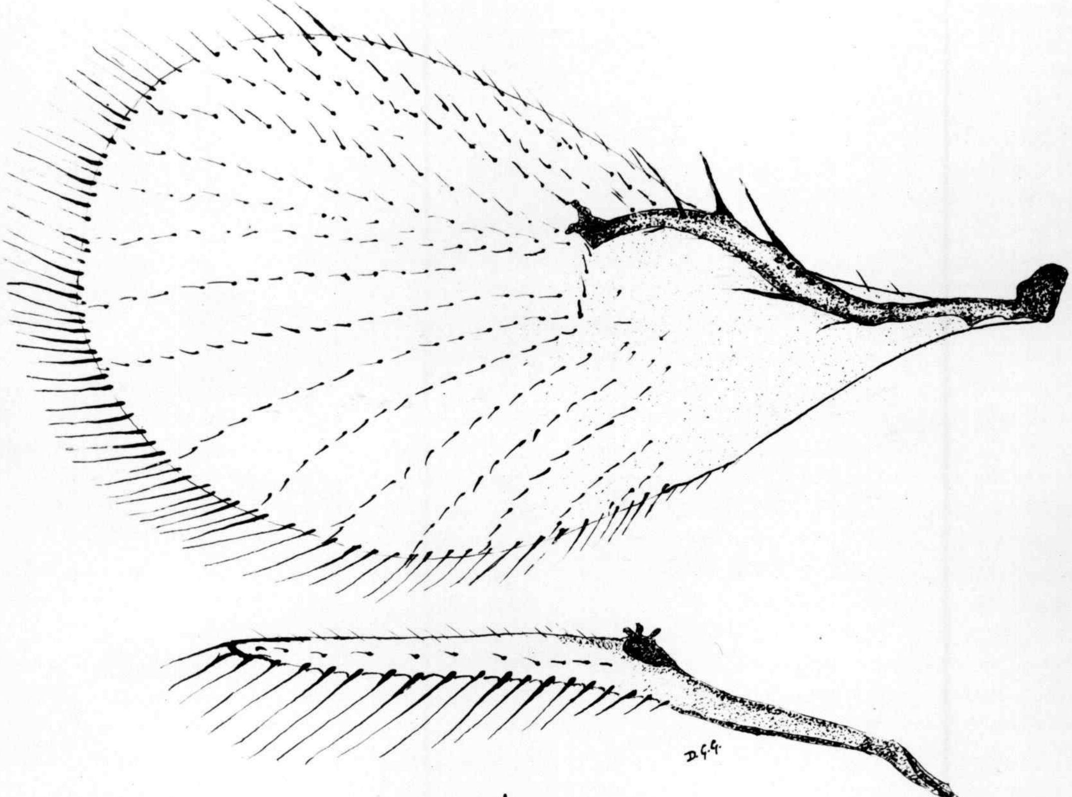

2.

PLATE II

Fig. 1. Wings of T. minutum, enlarged about 260 times.

Fig. 2. A. Male antenna of T. minutum.
B. Female antenna of T. minutum.
Both enlarged about 740 times.

PLATE II




1.


2 A.

2 B.

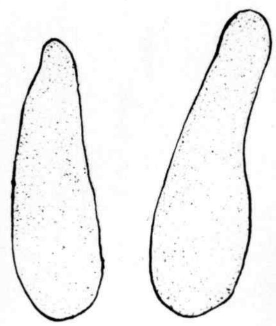
2.

PLATE III

Fig. A. Eggs of *T. minutum*, enlarged 460 times.

Fig. B. Egg of *Sitotroga cerealella* Oliv., showing emergence hole (a) of the parasite *T. minutum*. Host egg enlarged about 90 times.

PLATE III



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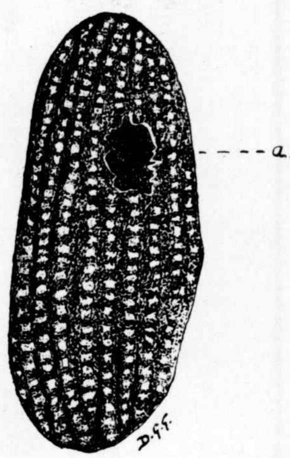


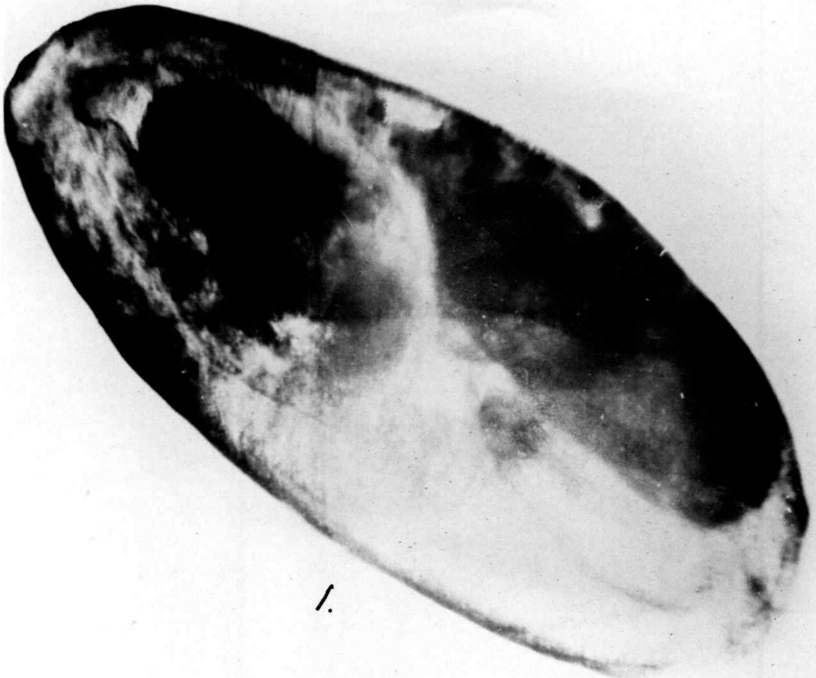

B.

PLATE IV

Fig. 1. Photomicrograph of parasitized grain moth egg showing two parasites in pre-pupal stage. Enlarged 275 times.

Fig. 2. Photomicrograph of two pupae of *T. minutum* within the egg of the grain moth. Enlarged 275 times.

PLATE IV



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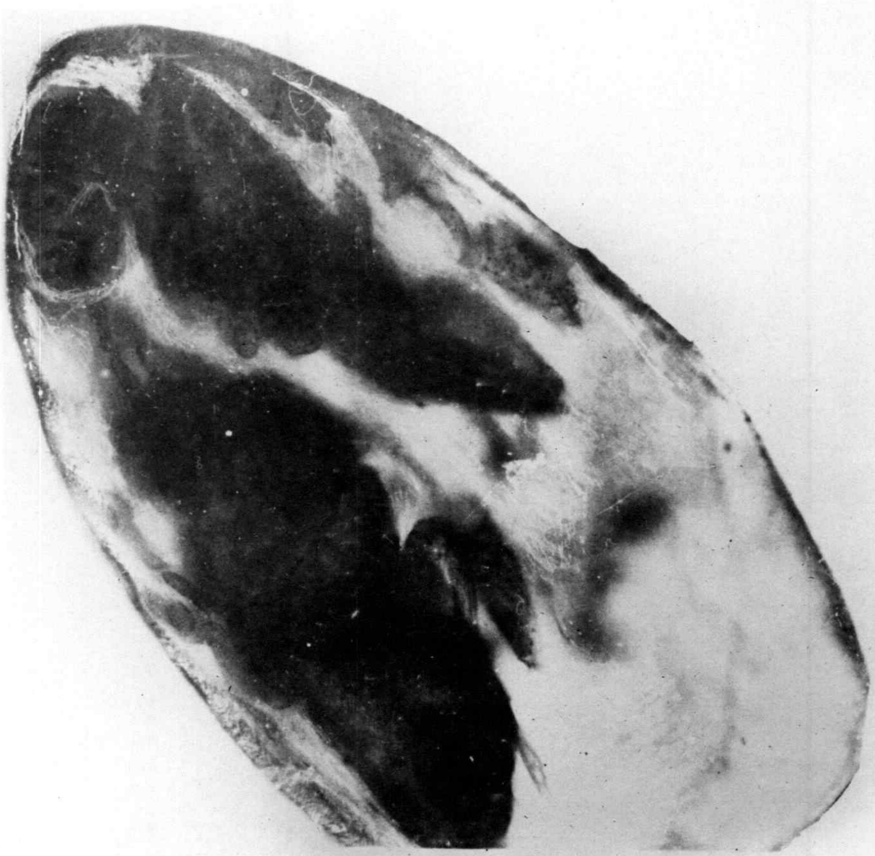
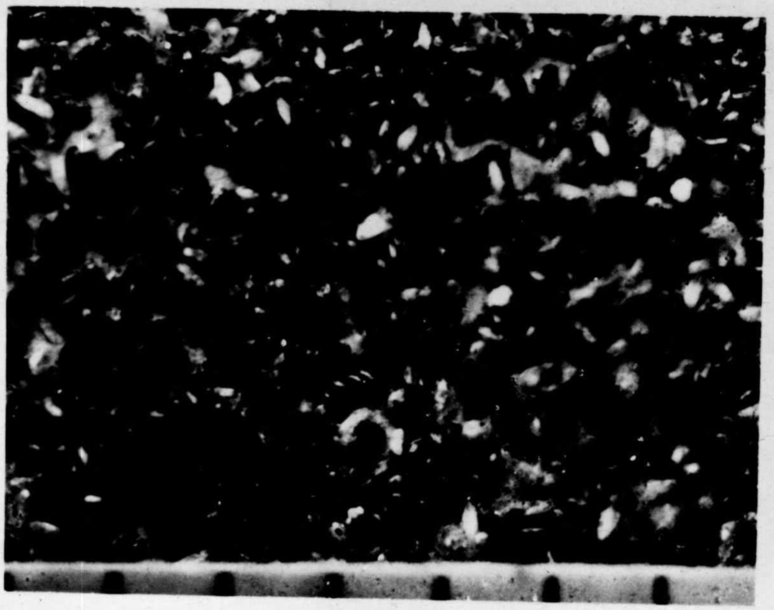


2.

PLATE V

Figs. 1, 2, and 3. Sections of cardboard discs containing grain moth eggs parasitized by T. minutum. The white spots are unparasitized eggs from which the grain moth larvae have emerged. Enlarged about 14 times.

PLATE V



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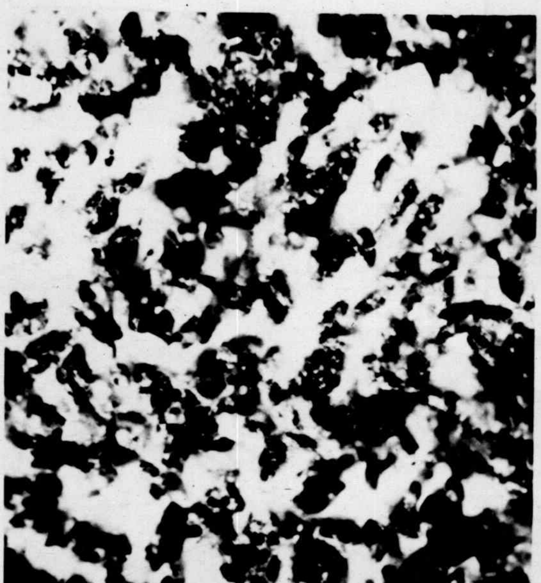

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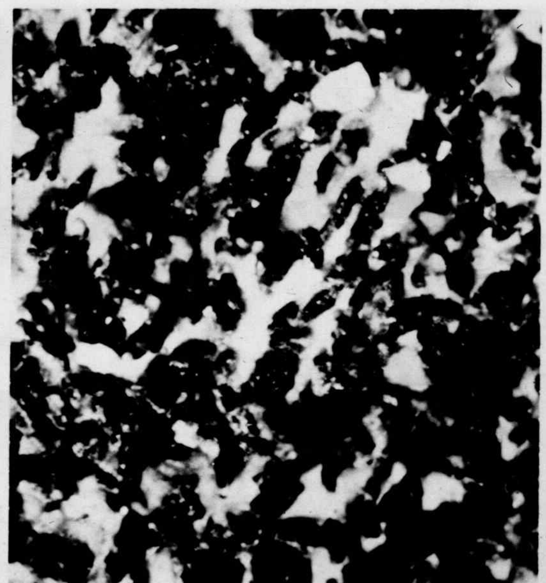


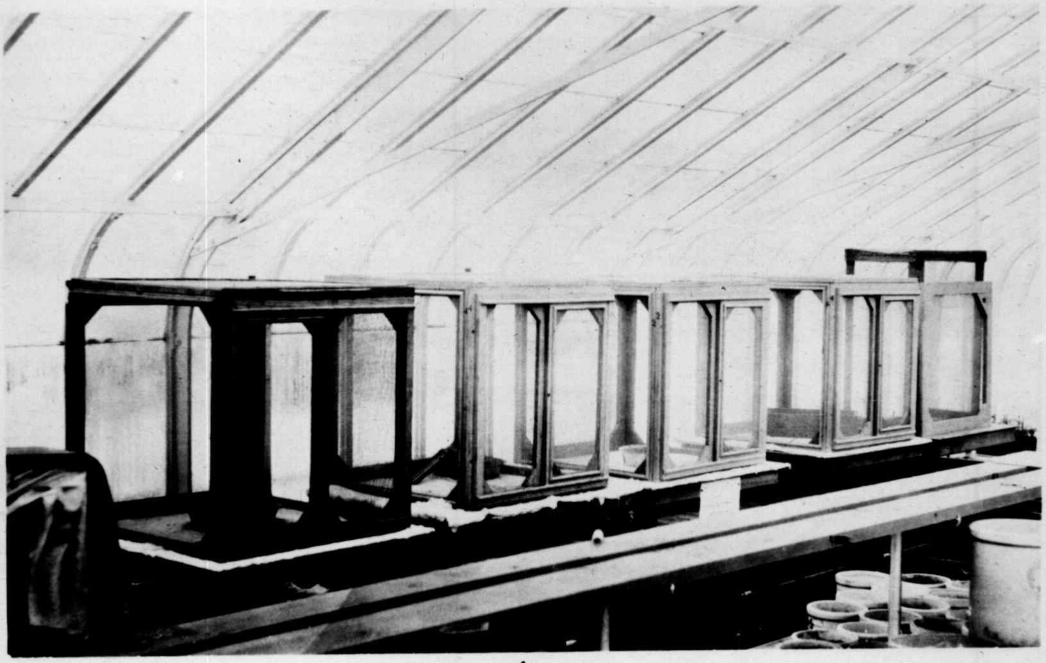
3.

## PLATE VI

Fig. 1. Cages used for the rearing of the laboratory host, *S. cerealella*, in the college greenhouses at Corvallis.

Fig. 2. View of the stand on which all cages were placed. Legs of the stand rest in baths of oil as shown, thus preventing mites and other predaceous insects from gaining access to the cage.

PLATE VI



1.

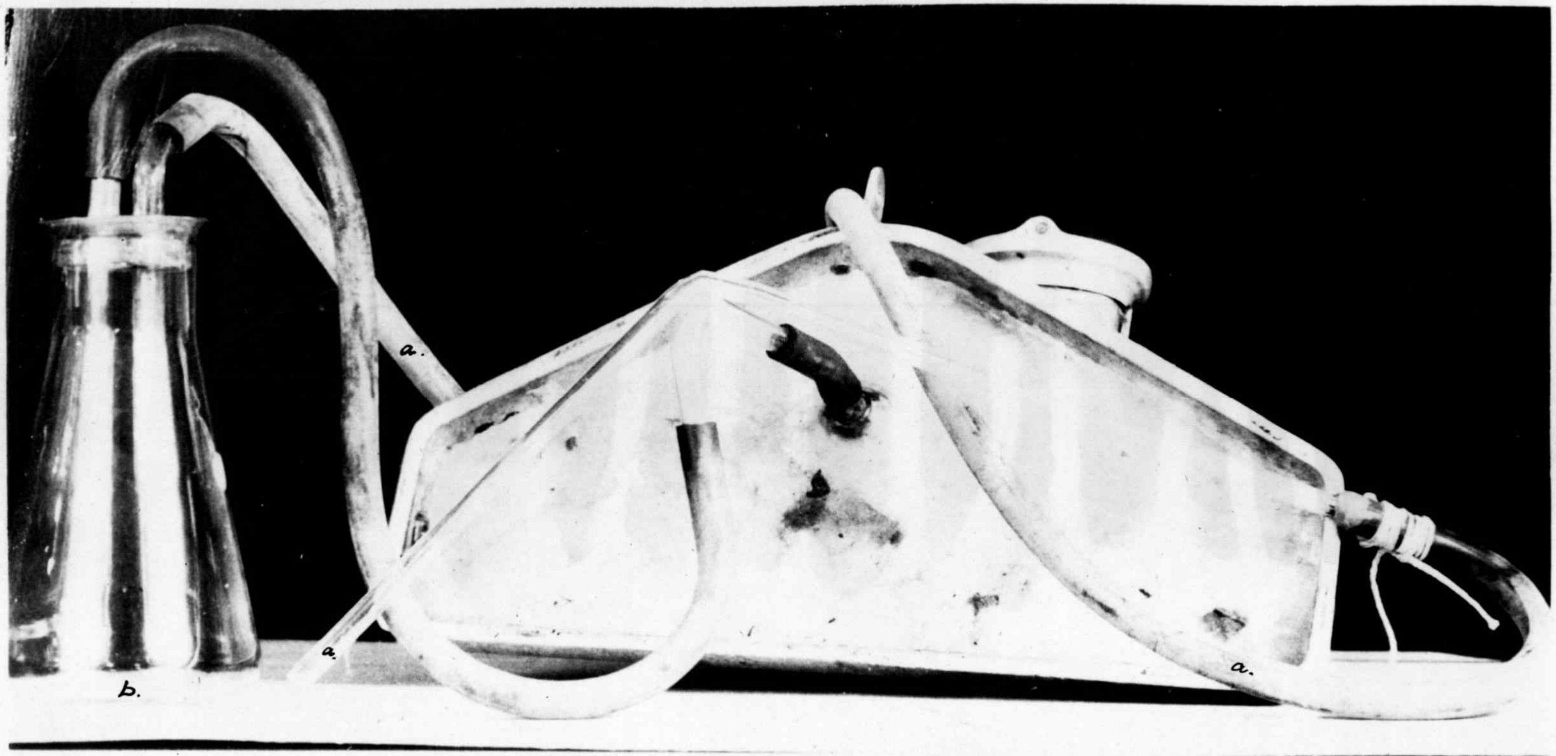

ORE. EXPERIMENT STATION
CODLING MOTH PARASITE
INVESTIGATIONS.

2.

PLATE VII

Vacuum collector, used in the quantity collection of S. cerealella. The moths are sucked through the glass tube and hose (a) into the collecting jar (b).

PLATE VII



## PLATE VIII

Fig. 1. Frigidaire machine used for storing of parasites previous to the making of shipments or liberations. (After Flanders).

Fig. 2. Apparatus used in securing of grain moth eggs and their preparation for parasitism:

A. Collecting jar, to be attached to vacuum sweeper.

B. Petri dishes, into which host eggs and parasites are introduced.

C. Egg deposition chamber.

D. Funnel and stand, used in filtering out grain moth eggs.

E. Cardboard discs, to which the grain moth eggs are shellaced.

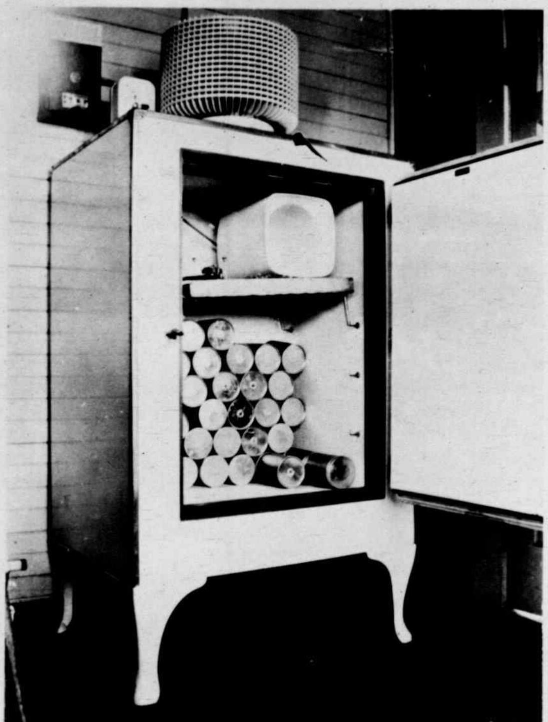
F. Filter paper.

G. Shellac and brush.

H. Small screen used in winnowing out eggs.

I. Jar to hold petri dish and egg deposition chamber.

PLATE VIII



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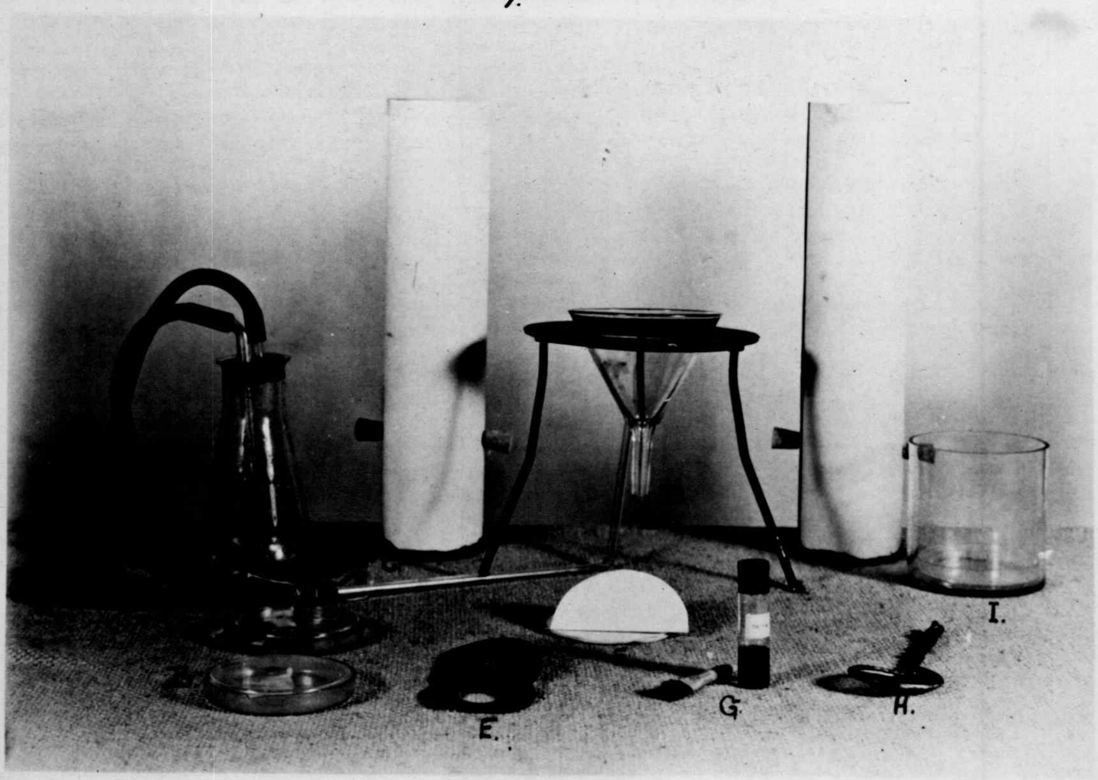



2.

PLATE IX

Adult of Ascogaster carpocapsae (Viereck), enlarged 19 times.

PLATE IX

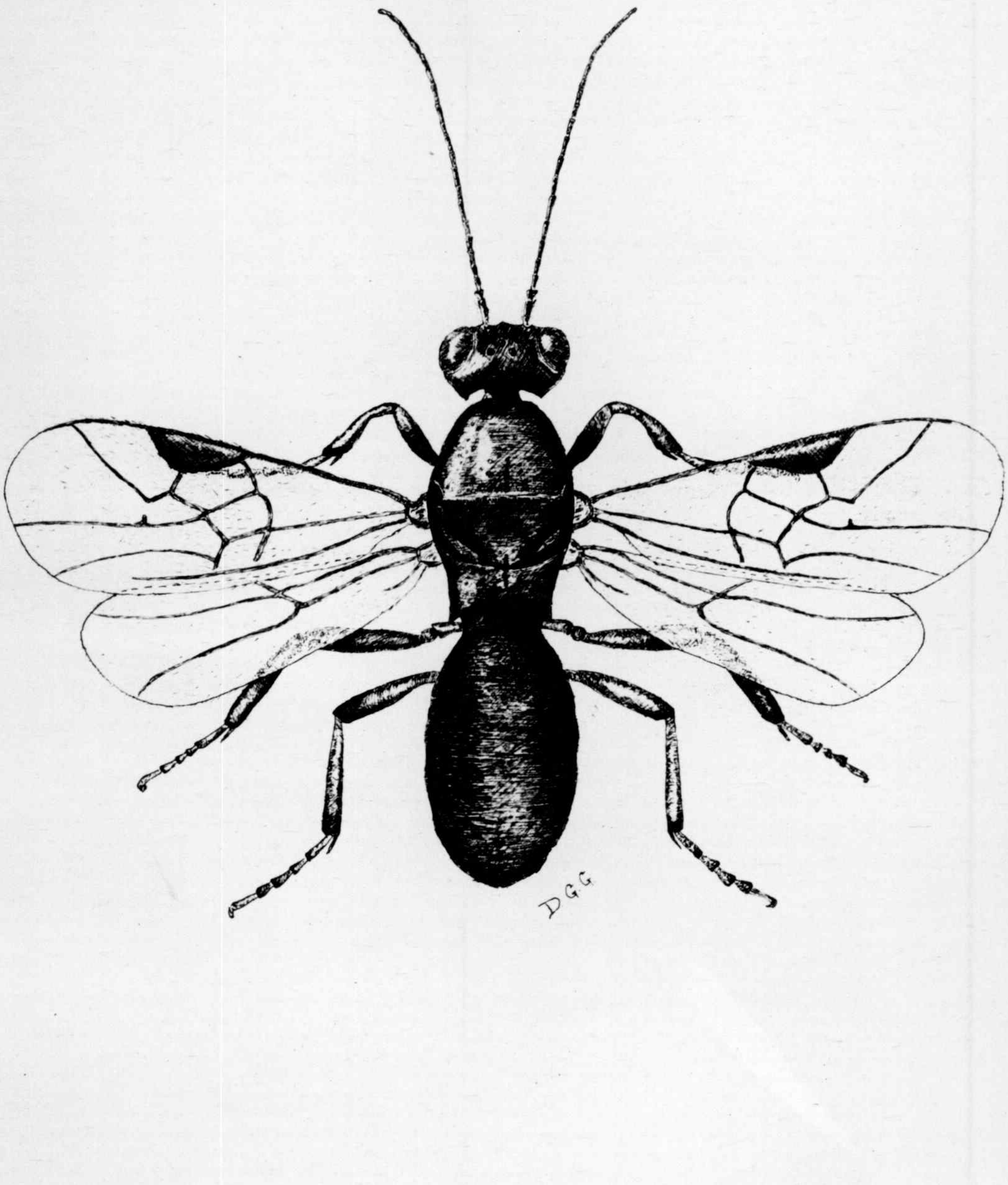


PLATE X

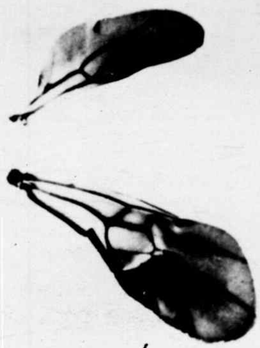
Fig. 1. Photomicrograph of wings of A. carpocapsae, enlarged 12 times.

Fig. 2. Photomicrograph of base of wing of A. carpocapsae, enlarged 108 times.

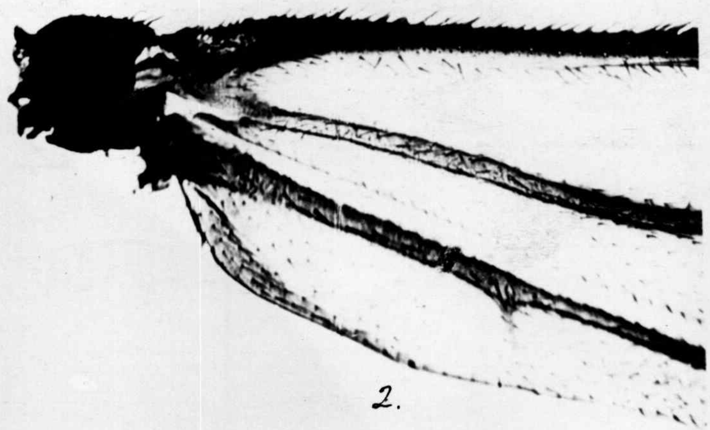
Fig. 3. A. Larva of A. carpocapsae (1) emerging from the codling moth host (2).
B. Larva of A. carpocapsae, enlarged about 3 times.

Fig. 4. Cocoons and pupae of A. carpocapsae within the old codling moth cocoons.

PLATE X



1.



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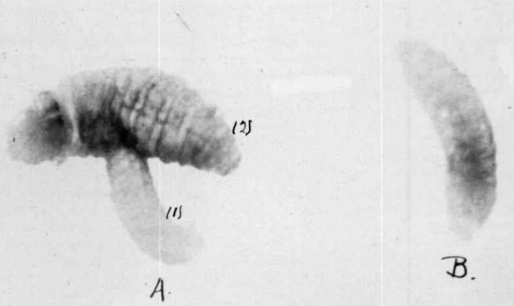


3.

4.