AN ABSTRACT OF THE THESIS OF

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Abstract approved:
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The purpose of this study was to determine the present status of introduced parasites of the omnivorous leaf tier, Cnephasia longana (Haworth) in Oregon.

The omnivorous leaf tier is native to Europe. It was introduced into North America around 1929 and became a serious pest of economic crops such as strawberry, Dutch iris and flax in Oregon. Its life history, habits, host plants and control measures have been investigated by several workers.

Fourteen species of parasites from France were introduced against this pest in Oregon during the years 1951 to 1954. Three of the introduced species were recovered during 1955 and 1956. They were: Bracon stabilis Wesmael, Bracon piger Wesmael, and Itoplectis maculator (F.), but none of these were recovered during a 1957 study. Since 1957, the status of these released parasites has not been investigated.

The study of introduced parasites during the present research was carried out at nine localities, including four previous release and recovery sites within the Willamette Valley of Oregon. The host larvae and pupae were collected and reared under insectary conditions at the OSU Entomology Department laboratory. The current study revealed that none of the introduced species have become established in the study areas. Factors preventing establishment are not known, but the physical factors, especially low winter temperatures and hot, dry summer conditions in Oregon, may have been detrimental to the introduced parasites.

Although the research was primarily concerned with investigating the present status of introduced parasites, four species of native parasites were recovered. They were: Enytus eureka (Ashm.), Itoplectis conquisitor (Say), Phytodietus burgessi (Cress.), and a hyperparasite, Mesochorus sp. All of these were reared from leaf tier larvar infesting vetch plants. Of these four species, E. eureka was found in the highest numbers. Its parasitism of C. longana was 17.14 percent.

Investigations of feeding habits of host larvae upon plantain, Plantago lanceolata L., and vetch, Vicia villosa Roth, were carried out under field conditions at Dallas, Oregon. The study confirmed that the first and second instar larvae feed as leaf-miners on plantain. The second instar migrates to vetch or other host plants and the remaining instars feed on the tender tips within webbed leaves.

A study of seasonal populations of host larvae was conducted in the field near Mt. Angel. The study revealed that the stages or instars of larval development were overlapping but that C. longana has only one generation a year in Western Oregon.

The emergence dates of the adult parasite, E. eureka, and moths were observed in the laboratory. The parasite started to emerge on June 6 which was nine days earlier than the host emergence. The peak emergence of the parasite was reached on June 18 while that of the host was reached on June 28.

It would appear that none of the introduced parasites have become established. Although as many as 14 species of native parasites have been recovered in Oregon. The results of this study suggest that the scattered distribution and low level of parasitism is probably not an important biological control agent in regulating omnivorous leaf tier population in Western Oregon.

Insect Parasites of the Omnivorous Leaf Tier,
Cnephasia longana (Haworth) in Oregon

by

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INSECT PARASITES OF THE OMNIVOROUS LEAF TIER, CNEPHASIA LONGANA (HAWORTH) IN OREGON

INTRODUCTION

The omnivorous leaf tier, Cnephasia longana (Haworth), is a member of the family Tortricidae, order Lepidoptera. It is native to Europe where it is not considered to be an important pest. The insect was introduced into North America, in Oregon, around 1929 and has become well established on the Pacific Coast ranging from British Columbia to California. It has become a serious pest of economic crops such as strawberry, Dutch iris, flax and leguminous plants.

The common name, omnivorous leaf tier, is an appropriate one since this species is known to infest over one hundred species of plants and the larvae tie the leaves together (Figure 3).

Due to the great losses suffered by strawberry and flax growers in the Willamette Valley of Oregon, control measures were extensively investigated. Chemical control has proved to be of limited value because the insect usually feeds within a protective covering of webbed leaves. Cultural control approaches were not completely effective. Biological control through parasite introduction was attempted during 1951 through 1954.

The status of released parasites was investigated by laboratory rearing of field-collected material during 1955 and 1956, but no further attempts at recovery were made.

The study of parasites of the omnivorous leaf tier was proposed to the author by Dr. P. O. Ritcher, Head, Department of Entomology, as a subject for a Master's Thesis. The study was conducted under the supervision of Dr. P. O. Ritcher, and Dr. E. A. Dickason. The purpose of the study was to determine the present status of parasites of the omnivorous leaf tier in Oregon. It is the hope of the author that the work presented may be helpful for future studies on the biological control of omnivorous leaf tier.

REVIEW OF LITERATURE

The omnivorous leaf tier, *Cnephasia longana* (Haworth), has been called "strawberry worm", "flax worm" and "tie worm" in relation to injury on various crops in Oregon (Rosenstiel, 1953). According to Edwards (1936) the insect belongs to the family Tortricidae and has been described under seven specific names. These are as follows: *Tortrix longana* (Haw.), *Tortrix ictericana* (Haw.), *Tortrix luridalbana* Mann., *Tortrix insolatana*, *Tortrix loewiana* Zeller, and *Cnephasia ictericana*.

A description of various life stages of *C. longana* has been given by Edwards *et al.* (1934), Edwards (1936) and Powell (1964).

Distribution

C. longana is native to Europe. It has been reported from England through western Europe, the Canary Islands and from northwestern Africa to Asia Minor. It was introduced in western North America where it has become established in southern British Columbia, the Puyallup Valley of Washington, the Willamette Valley of Oregon, and around the San Francisco and Monterey Bay areas of California (Powell, 1964).

In North America, it was first discovered in Oregon in 1929 when its larvae were found tunneling into strawberries in Clackamas County (Powell, 1964). By 1934 the species had become widely established throughout the Willamette Valley of Oregon and the Puyallup Valley of Washington (Edwards *et al.*, 1934). In 1948 it was reported in California, where larvae were feeding on flax and cultivated flowers in San Mateo County (Middlekauff, 1949).

Life History and Habits

The adult moths emerge from late May to late June and deposit eggs through most of July. The eggs are laid on the bark of trees, fence posts, and other more or less rough surfaces. The eggs soon hatch into small larvae that spin small silken hibernacula or overwintering cases near where the eggs were laid. The larvae remain within the hibernacula the balance of the summer and through the winter.

In early spring, beginning about the first of March, these young larvae are carried by air currents on a silken thread to a suitable host. For a short period these minute larvae mine the leaves of plants such as clover, vetch, and plantain. On emerging from the mines, they migrate to flowers and the tender tips of various kinds of plants (Schuh and Zeller, 1944).

Pupation begins about one month after the larvae are first noted in the field and continues for slightly over one month before the last larvae pupate. The duration of pupation varies somewhat, but will average about two weeks under insectary conditions (Edwards *et al.*, 1934). According to Meyrick (1895), in Europe the larvae were found from May to June and the moths were commonly found in July.

Egg laying habits were observed by Rosenstiel (1941b) who reported that moths oviposited on unpainted shingles, the bark of apple, ash, prune, cherry and oak trees where the surfaces were rough or cracked. No eggs were laid on smooth surfaces. The same author reported *C. longana* eggs were also found on nursery stock suggesting the species may be spread by transfer of nursery stock.

Overwintering of *C. longana* was observed by Edwards (1936), Ferguson (1939), and Rosenstiel (1940). They reported that the first instar larvae do not feed after hatching but seek shelter and overwinter in hibernaculum.

Wind-distribution of first instar larvae on a silken thread was observed by Ferguson (1938) and Rosenstiel (1940, 1941a). Ferguson (1938) noted that the ability to be carried in air currents was responsible for the species' rapid distribution.

Feeding habits of adult moth in the field have not been observed, but Edwards (1936) reported that in the laboratory adults fed readily upon a 50 percent honey and water solution.

Host Plants

Ferguson (1938) gave a list of 95 species of plants known to be hosts representing 30 plant families and 72 genera. An additional 12 species of new host plants were recorded by Ferguson (1939) which brings the total of recorded host plants to 107 species. Rosenstiel *et al.* (1944) gave evidence indicating that legumes, particularly vetch, clover and alfalfa appeared to be preferred hosts.

Economic Importance

Of the 95 species of host plants, 33 are plants of economic importance (Ferguson, 1938). Some of the economic plants, such as strawberry, Dutch iris, flax, wheat, peas, hops, filbert, clover, cultivated flowers and alfalfa were reported to be damaged by the insect (Middlekauff, 1949). Edwards (1936) noted that the importance of this species from an economic point of view depends upon the plant attacked. On strawberries the presence of worms within the berries or excrement-filled tunnels, without the worm being present, results in unmarketable fruit. It was reported during 1936 that strawberries grown in West Linn County of Oregon were 20 percent damaged which caused a loss to the grower of $40 to $50 per acre (Edwards, 1936). During 1939, strawberries in Hazel Green and North Howell in Marion County, Oregon, were up to 50 percent damaged (Ferguson, 1939). Allen (1959) also mentioned this insect as a serious pest of strawberry. Even low populations can cause damage by contaminating the fruit to be processed. During 1936, about 71 percent of Dutch iris grown at Canby were damaged (Edwards, 1936) and about 30 percent of flax plants grown in Palo Alto, California, were reported to be damaged during 1948 (Middlekauff, 1949).

Chemical Control

Extensive chemical control studies were carried out by several earlier workers. Field experiments for control of *C. longana* on strawberries gave little promise (Ferguson, 1938; Rosenstiel, 1940). Rosenstiel (1942) reported that chemical sprays applied on oak trees to repel adults before oviposition reduced the larval population significantly. Satisfactory control was obtained with modern insecticidal sprays on ornamentals in California (Pritchard *et al.*, 1949) and also on strawberries and nursery stock in Oregon (Rosenstiel, 1953).

Cultural Control

Studies on effect of crop rotation on injury to flax were made by Ferguson (1938) who reported the results appear promising where flax followed a cultivated crop. Late planting dates of flax to escape insect infestation were studied by Rosenstiel (1942) during 1941 and 1942, but gave no promising results.

Omnivorous Leaf Tier Parasites

Fourteen species of parasites have been introduced into Oregon in an attempt to establish them as biological control agents of the omnivorous leaf tier. Table 1 is a summary of introductions and recoveries based on various sources available. Insofar as known, the table is a complete record of Oregon releases. The parasites originated from France, were processed through the biological control station at Albany, California, and forwarded to Dr. R. G. Rosenstiel (Oregon State University) for field releases.

In addition to the recoveries listed in Table 1, 14 species of parasites have been recovered from the omnivorous leaf tier in Oregon as summarized in Table 2. Other than data collected by the writer during the thesis research program, Table 1 and 2 are hopefully complete literature reviews (see footnotes to Tables) of Oregon parasite recoveries. Specific literature relating to the various species will be cited in appropriate sections of the thesis.

Table 1. History of omnivorous leaf tier parasite introductions and releases in Oregon (adapted from sources cited in footnotes).

Introduction and release data				Recovery data	
Family and Species	Year	Number specimens[f]	Release sites	Year	Number specimens
Braconidae					
Clinocentrus	1951[a, b]	78[a]			
exserter Nees	1953[a]	18[a]	Mt. Angel, Canby[b]	not recovered[b]	
	1954[b]	?			
Microgaster	1951[b]	?			
tiro Rein	1952[a, b]	< 18[a]	Mt. Angel, Salem, Dayton[b]	cited in error[b]	2[g]
	1953[a, b]	17[a]		not cited[c]	
Microgaster sp.	1953[a]	< 10[a]	no release record[b]		
Apanteles	1951[b]	?			
nr. *clavatus*	1952[a, b]	> 62[a]	Mt. Angel, Salem, Dayton[b]	not recovered[b]	
(Prov.)	1953[a, b]	?			
Apanteles sp.	1953[a]	< 10[a]	no release record[b]		
Bracon piger	1951[b]	?			
Wesmael.	1952[a, b]	1188[a]	Mt. Angel, Salem, Canby[b]	1955[c]	2[d]
	1953[a, b]	37[a]		cited in error[b]	
	1954[a, b]	255[a]			
Bracon stabilis	1953[b]	?	Dayton, Canby[b]	1955-6[c]	36[g]
Wesmael.	1954[b]	?			(35♂, 1♀)
Rogas sp.	1951[a]	13[a]	no release record[b]		
Ichneumonidae					
Horogenes	1951[a, b]	63[a]			
fenestralis	1952[a, b]	21[a]	Mt. Angel, Salem, Canby[b]	not recovered[b]	
(Holm.)	1953[a, b]	54[a]			
	1954[b]	?			
Itoplectis	1952[b]	?			
maculator (F.)	1953[b]	?	Salem, Canby[b]	1955[b]	♂1[g]
	1954[b]	?		1955-6[c]	
Pimpline sp.	1952[a]	40[a]	no release record[b]		
Eulophidae					
Elachertus	1951[b]	?			
rufescens	1952[a]	288[a]	Mt. Angel, Salem, Dayton[b, e]	not recovered[b]	
(Rossi)	1953[b]	?			
Elachertus sp.	1953[a]	91[a]	no release record[b]		
Tachinidae					
Anoxycampta trizonata (Zelt.)	1954[b]	?	Canby[b]	not recovered[b]	

[a]Doutt, R. L. (personal communication, 1968).
[b]Ritcher, P. O. 1966.
[c]Rosenstiel, R. G. 1957.
[d]Based on specimens on OSU Insect Collection Museum.
[e]Peck, O. 1963. (Also cites Oregon release as *Stenomesius rufescens* Rossi.)
[f]Number of specimens received in shipment, but actual number released not known.
[g]Oman, P. W. (correspondence to OSU, 1957).

Table 2. History of omnivorous leaf tier parasite recoveries other than introduced species in Oregon (adapted from sources cited in footnotes, current research data included).

Family and Species	Locations	Year recovered 1936	1938	1957	1967
Braconidae					
Agathis cincta	Dallas, Marion			c	
Bracon hyslopi Vier	Canby, Albany	a	b	c	d
Bracon gelechiae (Ash.)	Canby, Albany	a	b	c	d
Eulophidae					
Tetrastichus bruchophagi	Dallas, Albany			c	
Tetrastichus sp.	Dallas, Mt. Angel			c	
Ichneumonidae					
Glypta sp.	Oregon	a			
Horogenes eureka (Ashm.)	Oregon, Mt. Angel	a	b'		e
Hoplocryptus sp.	Mt. Angel		b'		
Ischnus sp.	Mt. Angel		b'		
Ischnus inquisitorius atriceps (Cress.)	Albany				d
Itoplectis obesus Cush.	Mt. Angel		b'		
Itoplectis conquisitor (Say)	Mt. Angel				e
Phytodietus burgessi (Cress.)	Oregon	a			e
Stephanidae					
Chelonus sp.	Albany			c	

[a] Edwards, W. D. 1936.

[b] Ferguson, G. R. 1938.

[b'] Ferguson, G. R. 1939.

[c] Rosenstiel, R. G. 1957.

[d] Gray, K. (personal communication).

[e] Current research data, 1967.

RESEARCH PROCEDURE

Procedure in Field

Collecting of Host Larvae

The purposes of field collecting and laboratory rearing of *C. longana* larvae were twofold: 1) to determine whether the introduced European parasites were established, and 2) to determine if other parasites were present.

Collections of *C. longana* larvae and pupae were made at nine locations (see Table 6). The first four localities (Mt. Angel, Salem, Dayton and Canby) are areas where parasites of foreign origin were released (Table 1). Dallas, Oregon City, Tualatin, Brooks and Red Prairie are additional sites.

Infested vetch plants were collected periodically in order to obtain host larvae in various stages of development. The samples were placed in plastic bags and transported to the laboratory in portable ice boxes for examination and subsequent rearing.

Larval Population of *C. longana* on Plantain and Vetch

Under field conditions larvae were usually found on both plantain (*Plantago lanceolata* L.) and vetch (*Vicia villosa* Roth) when they grew in the same area. The idea that larvae change their host plants from plantain to vetch during later instars of their development seemed plausible. To confirm this possibility population sampling was carried out at Dallas where these two host plants grew together. The sampling was made periodically by the use of one-foot square quadral frames to cover the random areas from which the samples were taken. Ten samples of plantain or vetch were collected on each collection date, then placed in plastic bags, and returned to the laboratory for examination.

Seasonal Populations of Host Larvae

Sampling to study the abundance of host larvae and their stages or instars was carried out in an undisturbed weedy grove of oak trees near Mt. Angel. The samples were made on three collection dates, which represented early-season, mid-season and late-season of the host larvae activity period. On each sampling date, 100 randomly selected, infested, vetch (*V. villosa*) stems were collected and grouped in sub-samples of ten stems per plastic bag. The samples were kept in portable ice boxes and brought into the laboratory for counting and instar separation.

Emergence of Adult Host Insect and Parasites Under Field Conditions

The emergence of moths and parasites under field conditions was observed at Mt. Angel by means of taking samples at weekly intervals throughout the 1967 activity period of the insects. The samples were collected from the previously mentioned undisturbed area by sweeping with an insect net. Ten sweep samples were made and the collections transferred to a plastic bag at ten different locations until a total of 100 sweeps were obtained on each sampling date. After returning to the laboratory, moths and parasites were counted, the sexes recorded. Confirmation of insect species was made by Dr. Hodges of the USDA Entomology Division.

Laboratory Procedure

Larval Instar Separation

The purpose in determining the instars of larvae was an attempt to obtain information on the particular instar in which the larvae are attacked by the parasites under field conditions.

Collected larvae were kept in a refrigerator at temperature 35° F. for an hour to render the larvae inactive. The larvae were then taken from the refrigerator and the head capsules measured under a binocular microscope equipped with a calibrated eyepiece.

Using the work done on instar measurements by Ferguson in 1938 following Dyar's Law, it was possible to separate the larvae into six instars based on width of the head capsule.

Rearing Techniques

The rearing of parasites was conducted under insectory conditions at the Oregon State University Entomology Department laboratory.

After the larvae were separated by instars they were reared individually in 2-dram glass vials. They were fed with vetch leaves, *Vicia* spp., which had been grown on the Entomology farm and were free from omnivorous leaf tier infestation and free from insecticide contamination. The vials were loosely plugged with cotton. Each ten vials were grouped together and placed in a plastic container covered with a screen lid (Figure 1). Plant food had to be renewed at four day intervals.

The larvae were observed on alternate days until parasites or moths emerged or larvae died. Records of locality where collected, larval instars and dates of emergence were made.

Emerged parasites were kept in vials and preserved in 70 percent ethyl alcohol. The moths were killed and either pinned or layered in plastic boxes. The determination of parasite species was made by M. L. Walkley and host insect was made by R. W. Hodges, both entomologists of the Entomology Division, USDA.

While rearing parasites in the laboratory, some of the host insects died in the larval or pupal stage. All of the dead larvae or pupae were preserved in 70 percent ethyl alcohol.

Figure 1. Glass vials and plastic containers used for rearing parasites of Cnephasia longana (Haw.)

RESULTS AND DISCUSSION

Field Sampling Data

Host Larval Populations on Plantain and Vetch

A study of the relationships between early-season and late-season host plants of *C. longana* was carried out in a 20 by 200 foot roadside area near Dallas in Polk County. The samples were collected at random, brought into the laboratory, and larvae counted and separated into instars. The results are summarized in Table 3.

Second instar larvae were found on both plantain and vetch on the first collection date (Table 3). At this time second instar larvae were found most commonly on plantain, *Plantago lanceolata* L., while only two second instar larvae were found on vetch, *Vicia villosa* Roth. On the following three collection dates no larvae were found on plantain, but vacated frass-filled tunnels remained on the leaves. However, third, fourth, fifth and sixth instar larvae (including one pupa) were found on vetch in these three collections.

These results confirm that only the first and second instar larvae mine in the leaves of plantain early in the season (Figure 2). The remaining instars feed in a protected habitat on webbed leaves of hosts such as vetch (Figure 3). During this study first instar larvae were not recovered from either host because sampling began rather late. Under microscopic examination, the minute head capsules of

Table 3. Comparison in populations of _C. longana_ larvae on plantain and vetch under field conditions at Dallas, Polk County, 1967.

Collection date	Plantain									Vetch									
	No. leaves coll.	No. inj. leaves	No. larvae coll.	Instar						No. stems coll.	No. inj. stems	No. larvae coll.	Instar						
				I	II	III	IV	V	VI				I	II	III	IV	V	VI	Pupa
May 13	217	32	20	0	20	0	0	0	0	93	11	10	0	2	8	0	0	0	0
May 25	265	25	0	0	0	0	0	0	0	100	17	17	0	0	10	5	2	0	0
June 9	243	27	0	0	0	0	0	0	0	105	25	20	0	0	0	3	8	9	0
June 16	247	31	0	0	0	0	0	0	0	100	10	4	0	0	0	0	0	3	1
Total	972	115	20	0	20	0	0	0	0	398	63	51	0	2	18	8	10	12	1

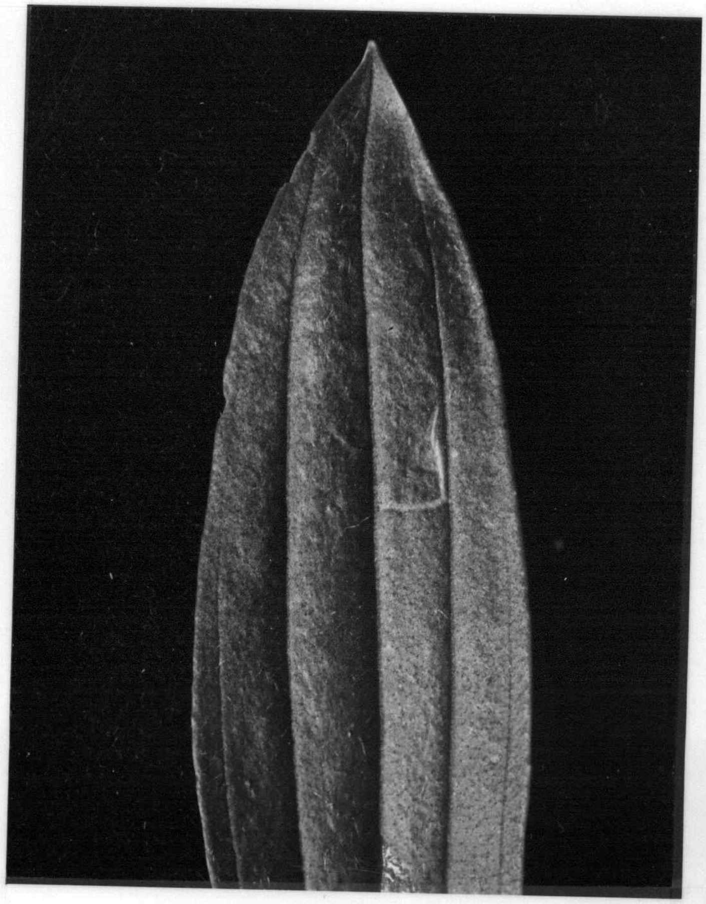

Figure 2. Tunnel made by C. longana larva on plantain leaf.

Figure 3. Injury to terminal shoot of vetch by C. longana larva.

the first instar larvae were commonly found within the mines in plantain leaves.

Seasonal Populations of Host Larvae on Vetch Plant

The population trends of host larvae in the field were studied in a relatively undisturbed, weedy grove of oak trees near Mt. Angel. The samples were taken on three collection dates, which were designated as early-season, mid-season and late-season periods of larval activity. Collections were made on May 20, June 1 and June 12. Samples were brought into the laboratory and the larvae separated into instars by means of head capsule measurement. Results are summarized in Table 4. First instar larvae were not collected and second instar larvae were not abundant due to the fact that sampling started rather late.

In Figure 4, the population data from Table 4 have been transposed to percentage figures and plotted to illustrate progression of larval instars by field collecting periods.

In the early-season collection, the larvae of second, third, fourth and fifth instar were found in the field with the fourth instar larvae most abundant. In the mid-season collection the third, fourth, fifth and sixth instar larvae were present in the field with fifth instar larvae most abundant. In the late-season collection, fourth instar larvae were still present in small numbers, with sixth instar larvae most abundant.

Table 4. Population of C. longana larvae on vetch during different periods of the season, Mt. Angel, Oregon, 1967.

Collection Period	Number Collected	Numbers of larvae by instar						
		I	II	III	IV	V	VI	Pupae
Early-season	48		2	10	28	8		
Mid-season	52			4	12	30	6	
Late-season	50				4	14	30	2

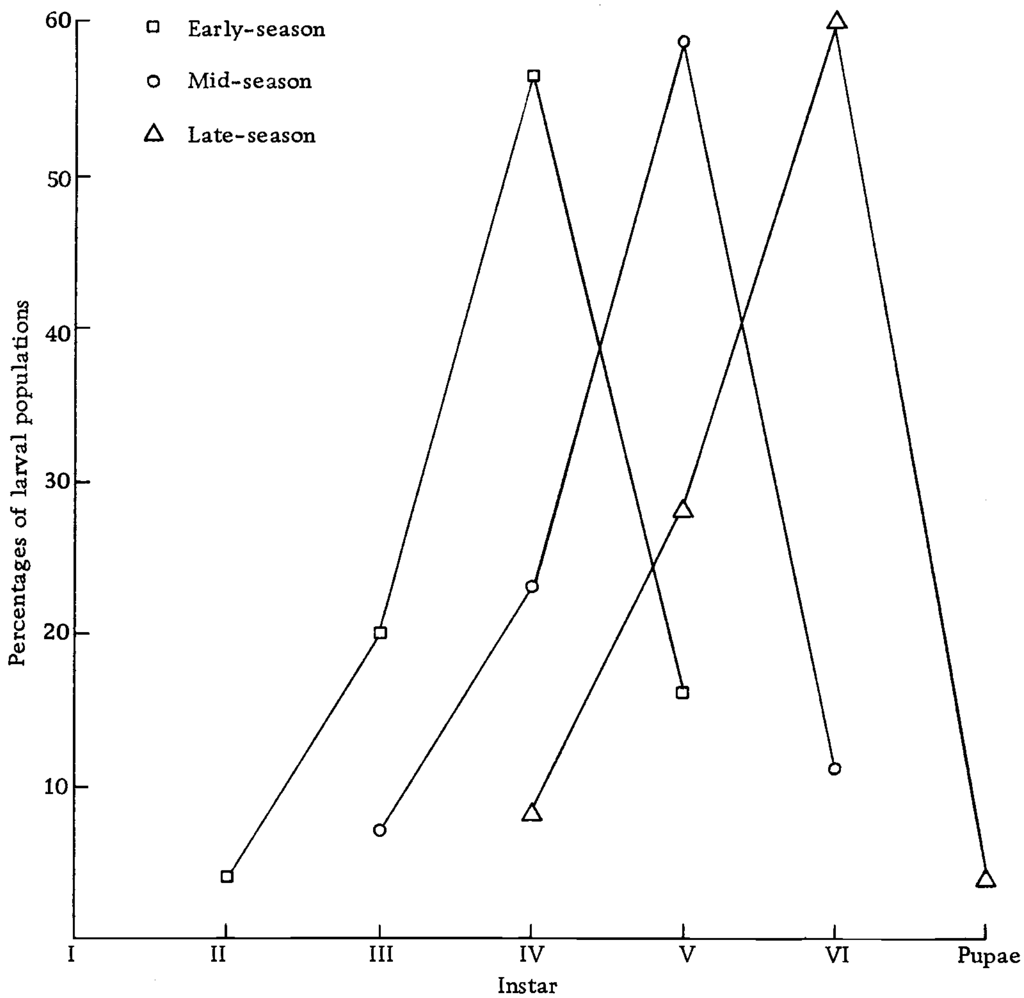

Figure 4. Populations of C. longana larvae on early-season, mid-season and late-season collecting dates (Adapted from Table 4).

This study shows that the larval stages of development overlapped, probably as a result of variation in time of emergence of overwintering larvae.

The Emergence of Adult *C. longana* Under Field Conditions

This study was conducted in the previously mentioned area near Mt. Angel. The samples were taken at weekly intervals by means of sweeping the study area with an insect net. The study was conducted from June 16 through September 1, 1967. The results of the study were summarized in Table 5.

Table 5 shows the total numbers of moths collected at different dates. The population reached peak numbers within one week after moths appeared and then dropped rapidly during the following weeks. Moths had disappeared from the field by the last week of August. Although there is considerable overlapping of larval stages, this study confirms that *C. longana* has a single generation a year in western Oregon. The sex ratio of males to females obtained during this study was 1:2.

Originally this experiment was designed to compare field emergence and population density of omnivorous leaf tier moths with emergence and population density of its parasites. The experiment was initiated early in the study and prior to any knowledge of the expected yield of parasites. Field sweeping with an insect net did not reveal

Table 5. The emergence of adult host, C. longana and parasite, E. eureka under field conditions at Mt. Angel, Oregon, 1967.

Collection Date	Host (C. longana)			Parasites		
	No. Coll.	♂	♀	No. Coll.	♂	♀
June 16						
June 23	2	1	1	1	1	
June 29	17	8	9			
July 6	10	2	8	1		1
July 10	4	1	3			
July 17	4	1	3			
July 24	2		2	1		1
Aug. 3	1	1				
Aug. 11	1		1			
Aug. 18	1	1				
Aug. 25						
Sept. 1						
Total	42	15	27	3	1	2

any suspected parasites except for single specimen collected on June 23, July 6 and July 24. Thus it was not possible to show the leaf tier-parasite population relationships under field conditions.

One other field experiment failed to produce sufficient data for inclusion in the thesis. At the time a rather high yield of parasites was being obtained in laboratory rearing of host larvae material collected at Mt. Angel (laboratory data will be covered in a later section); it was suspected that parasites might be those originally released and later recovered at this site (Table 1). In the event this was the situation, an experiment on dispersion from the release site was established by interval sampling (sweeping host plants with an insect net) along cardinal compass points up to four miles from the original release site.

Laboratory Rearing Data

General Summary of Parasite Rearing

The results of parasite rearing under insectary conditions are summarized in Table 6. Fifty-four adult hymenopterous parasites and 255 adult moths were obtained from 663 larvae and 19 pupae of *C. longana* collected from nine locations in the Willamette Valley of Oregon. *Mesochorus* sp. (Table 7) is considered a hyperparasite. The larvae and pupae that died as a result of diseases or

Table 6. Locations, number of larvae and pupae collected, numbers of moths and parasites emerged from C. longana larvae, 1967.

Location of collection	No. host larvae	Rearing mortality	No. moths emerged	No. parasites emerged
Mt. Angel[a]	280	138	92	50
	10[b]	5	5	
Salem[a]	49	31	18	
Dayton[a]	9	9		
Canby[a]	17	14	2	1
Dallas	50	37	13	
Oregon City	231	108	120	3
Tualatin	20	18	2	
Brooks	4	3	1	
Red Prairie	3	1	2	___
Total	673	364	255	54

[a]Release site.

[b]Pupae.

Table 7. Species of parasites (Ichneumonidae), percentages of parasitism and collecting locations, 1967.

Species reared	Locations	% parasitism
Ichneumonidae		
Enytus eureka (Ashm.)	Mt. Angel	17.14
	Oregon City	1.30
Itoplectis conquisitor (Say)	Mt. Angel	0.36
Phytodietus burgessi (Cress.)	Canby	5.88
Mesochorus sp. [a]	Mt. Angel	______
Total		24.68

[a]Hyperparasite.

other causes during rearing are listed in the record column of Table 6. Parasite determination revealed that none of the introduced species (Table 1) was recovered during these studies. All hymenopterous parasites which were reared during the current study (Table 7) belong to the family Ichneumonidae. A single specimen of hyperparasite also belong to Ichneumonidae. They represent four species as shown in Table 7.

The Emergence of Adult Moths and Parasites Under Insectary Conditions

Enytus eureka was the only parasite recovered in biologically significant numbers (Table 7). This species was recovered from two locations, Mt. Angel and Oregon City, but only three specimens were recovered from the latter site. Thus, the following discussion will be based on the emergence of the species *E. eureka* and the host insect obtained at Mt. Angel only.

Larvae and pupae collected from Mt. Angel were reared under insectary conditions. The larvae were observed on alternate days until they died or either a parasite or moth emerged. The dates of emergence were recorded and the sexes determined.

Parasite emergence began in early June, gradually increased in numbers and reached a peak population on June 18, and then gradually declined in numbers until the end of June (Figure 5). The last parasite emerged on June 28.. The sex ratio of male to female was 1:3.5 .

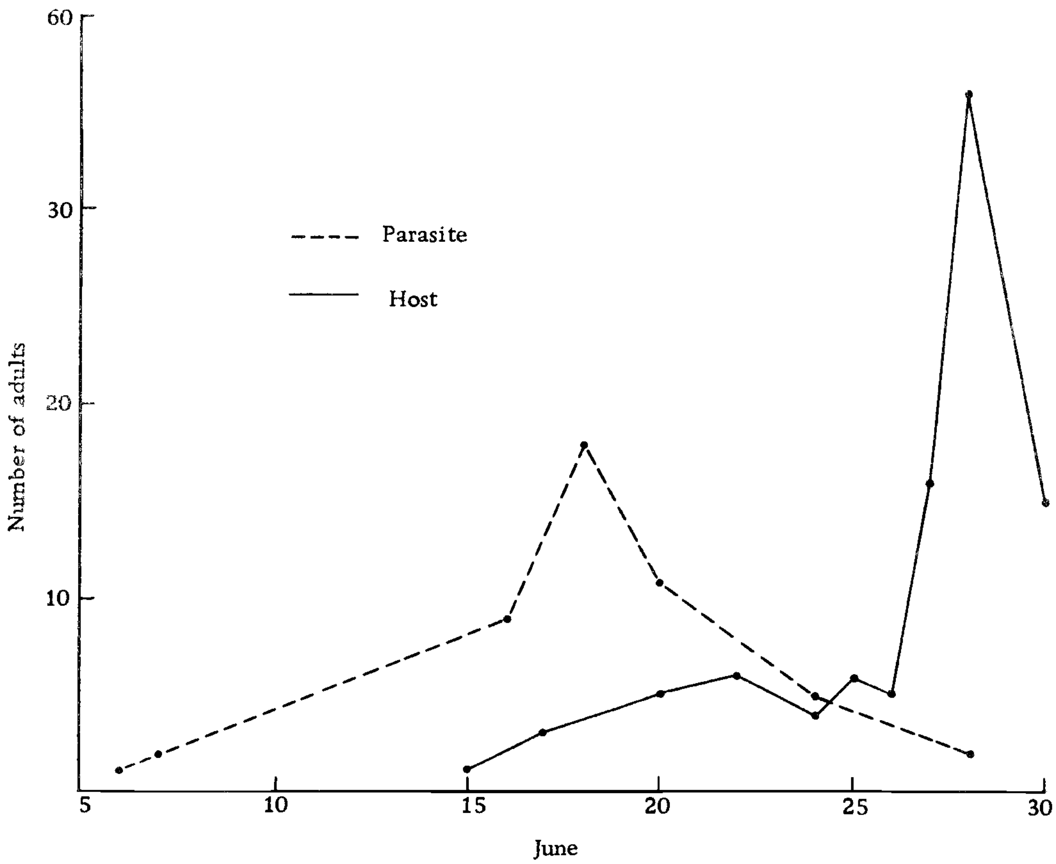

Figure 5. Comparison of emergence dates of adult host insect, C. longana, and the parasite, E. eureka, reared under insectary conditions.

Emergence dates of host insect, C. longana under insectary conditions are also shown in Figure 5. The first moth emerged during mid-June, nine days later than parasites began emerging. The number of moths emerging slowly increased until late June and then increased rapidly reaching a peak on June 28. Following this period, the population dropped rapidly toward the end of June. Peak emergence of moths occurred 10 days after peak emergence of parasites. The sex ratio of male to female moths was 1:2.7.

Moth emergence under laboratory conditions (Figure 5) began one week earlier than under field conditions (Table 5) and terminated almost six weeks earlier. Suprisingly, however, the peak emergence fell during the same period under both conditions.

Review of Species of Parasites Recovered During 1967

Enytus eureka (Ashmead) [= Horogenes eureka (Ash.)]

According to Muesebeck et al.(1951), this species belongs to the family Ichneumonidae, genus Horogenes. The species was first described by Ashmead (1889) in May, 1886, as Limneria eureka. In 1903, Cameron (1903) described a specimen collected from an area near Stanford University, California, and erected the name Enytus maculipes (Baker, 1903). In 1925, Viereck (1925) gave a description of the same species under the name Campoplex (Dioctes) rosaceanae.

The specimens reared from C. longana larvae during the current study were determined by L. M. Walkley under the name *Enytus eureka* which equals *Horogenes eureka*.

This species is known to have a distribution from British Columbia to southern California. It is known to parasitize the omnivorous leaf tier, *C. longana*, orange tortrix, *Argyrotaenia citrana* (Fernald), *Archips rosaceana* (Harr.) (Muesbeck *et al.*, 1951), and *Coleophora visidiflorella* Walsingham (Tilden, 1954).

Enytus (*Horogenes*) *eureka* (Ashmead) (Figure 6) was the only species of parasite recovered in any numbers during this study (Table 7). Following the USDA identification of this species (1967, personal communication), a further study was conducted by that agency to confirm it was not *Horogenes fenestralis*; a species released during the 1951-1954 seasons at the 1967 collection site (Table 1). It was confirmed as *E. eureka*, a species previously recovered from the omnivorous leaf tier at the Mt. Angel release site (Table 2). During this study, parasites were recovered from larvae collected as instars fourth, fifth and sixth (Table 8 and 9). It must be remembered that at the time this study was being conducted there was no way of anticipating which of the many sampling sites would produce parasites. The data suggests several possibilities. First, possibly only larvae beyond the third instar are attacked because none of the earlier instar produced parasites. Or, secondly, it is possible that rather than a host preferential factor; a seasonal factor may have

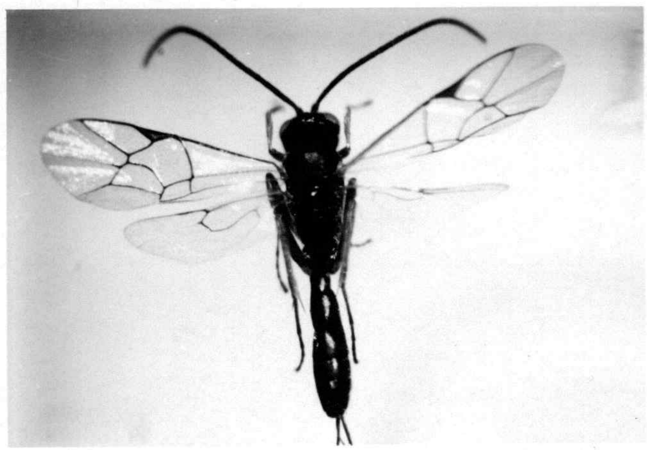

Figure 6. A female Enytus eureka (Ashm.), reared from omnivorous leaf tier larva, Mt. Angel, Oregon, 1967.

Table 8. Insectary rearing data for Enytus eureka recovered from field-collected omnivorous leaf tier larvae collected at Mt. Angel, Oregon, 1967.

Collection date	Host larvae Instar	Host larvae No.	Parasite reared No.	Parasite reared Sexes Male	Parasite reared Sexes Female	Host instar	Percent parasitism
May 20	II	9					
	III	5					
	IV	10					
	V	15					
June 1	III	14					
	IV	29	2		2	VI	6.89
	V	20	2	1	1	VI	10.00
	VI	15					
June 10	IV	8	2		2	VI	25.00
	V	22	4		4	V, VI	18.18
	VI	71	18	4	14	VI	25.35
June 12	IV	3	2		2	V, VI	66.66
	V	4	4	1	3	V, VI	100.00
	VI	55	14	4	10	VI	25.45
Totals		280	48	10	38	V, VI	
Average parasitism for season							17.14

Table 9. Insectary rearing data for Enytus eureka recovered from field-collected omnivorous leaf tier larvae collected at Oregon City, Oregon, 1967.

Collection date	Host larvae Instar	Host larvae No.	Parasite reared No.	Parasite reared Sexes Male	Parasite reared Sexes Female	Host instar	Percent parasitism
May 27	IV	20	2		2	VI	10.00
	V	30	1	1		VI	3.33
	VI	35					
June 14	IV	30					
	V	11					
	VI	90	—	—	—	—	
Totals		216	3	1	2	VI	
Average parasitism for season							1.30

been measured. Recoveries were made from collections on June 1 (Table 8) and May 27 (Table 9). It was possible that parasites were not present in the field until late May and attacked larvae during the stadia most commonly present for that period of host development.

It is also possible that the instars collected were not necessarily the instars attacked by adult parasites in the field. For example, the June 10 collection (Table 8) in which the fourth, fifth and sixth instar larvae which yielded parasites may have been attacked in the field during earlier instars. Although, in general, infestation percentages increased during later collections and the seasonal factor may have a definite relationship to host development.

E. eureka is an endoparasite of larvae. Although oviposition was not observed presumably the female parasite deposited eggs internally in host larva. The parasite larvae feed on the body content of the host. As soon as the host died, the full grown parasite larva emerged from the host by cutting a hole through the host integument. During this study, the parasites emerged from fifth and sixth instar host larvae (Table 8 and 9). On two occasions, the actual emergence of a parasite was observed by the writer. It reached the exterior between the third and fourth abdominal segments of the host larvae. Upon its emergence, the parasite larva spun a cocoon near the dead host. Pupation took place within the cocoons and lasted for eight to 12 days. The adult reached the exterior by chewing a hole through the cocoon (Figure 7). Only one adult parasite was obtained from each host larva.

During the 1967 season, parasitism of E. eureka at Mt. Angel was 17.14 percent and at Oregon City only 1.30 percent. It is doubtful if the species exerts a significant population control on the omnivorous leaf tier, particularly since the parasite is now known to have been present in the Mt. Angel area for more than 30 years (Table 2). Edwards (1936) recovered the species but he did not give the percentages of parasitism. Ferguson (1939) also found E. eureka attacking omnivorous leaf tier but its abundance was not mentioned. The reasons for the species not becoming more abundant during this period of time are not known, but one obvious explanation may be the lack of synchronization with the hosts. For example, early-season developing larvae were not parasitized.

Itoplectis conquisitor (Say)

Although only a single specimen of this species was recovered (Figure 8) from the Mt. Angel collection site, this is the first record of this species in a western state. Itoplectis maculator (F.) was released at Salem and Canby (Table 1) and later recovered. For this reason the USDA entomologists checked their I. conquisitor determination against I. maculator, but were convinced it was not a recovery of the released species (1967, personal communication). The single

Figure 7. A cocoon of Enytus eureka (Ashm.)

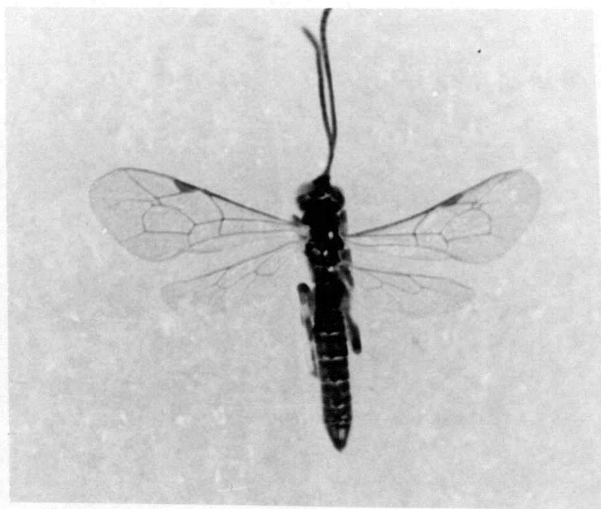

Figure 8. A male Itoplectis conquisitor (Say), reared from omnivorous leaf tier larva, Mt. Angel, Oregon, 1967.

specimen was reared from a larva collected during the last (sixth) instar. It developed within the host, emerged to spin a cocoon, and completed pupation within seven days.

In contrast to the other parasites discussed, there is a great deal of literature relating to this species. Very briefly, the most pertinent literature is as follows:

The species was described by Say in 1836 and Townes (1940) and Muesebeck *et al.* (1951) give a complete history of the synonomy of the species and Muesebeck *et al.* lists the distribution from the Atlantic to Rocky Mountain states. These two papers list ten known families of Lepidoptera and one of Coleoptera (Cerambycidae) that are attacked by the species as a primary parasite, but Townes also reports it as occasionally being a secondary parasite. Mating habits were studied under laboratory conditions by Liu (1926). Apparently it may attack insects in the pupal stage within cocoons as reported by Weed and Fiske (1900, p. 33-34) and Johnston (1913), or during the larval stage as found during this study and reported by Weed *et al.* (1900) and Dorner (1936).

Townes (1940) reports the insect overwinters in a host pupa and Criddle (1921) states there are two generations a year with the first generation dependent mainly on *Malacosoma*. This observation may be applicable in Oregon where *Malacosoma* (tent caterpillars) are very common. Fiske (1903) states the developmental period from egg to adult requires about 20 days. Adults feed on juices exuding from ovipositor wounds in the host according to Johnston (1913). Parasitism has been reported up to 20 percent on tent caterpillars by Criddle (1923) and up to 79 percent on the spruce budworm by Twinn (1938).

Phytodietus burgessi (Cress.)

During the summer of 1967, a single specimen of *P. burgessi* was reared from one of 17 larvae collected near Canby on June 14. It was an ectoparasite of a full grown *C. longana* larva. The mouth parts of the parasite larva were firmly attached dorsally on the host at the second abdominal segment. The larva consumed the body content of the host until the host died. Then the full grown larva left the host and constructed an elongate cocoon. During this study, a female parasite died in the cocoon prior to emergence and this is the reason for the misshapen and twisted wing appearance in Figure 9. Possibly it was too dry in the rearing vial for the adult to emerge from the cocoon.

This species was also reared from the omnivorous leaf tier in Oregon during 1936 by Edwards (1936), but the percentage of parasitism was not reported.

According to Muesebeck *et al.*(1951) the members of the tribe Phytodietini are common parasites of Lepidoptera. The egg is

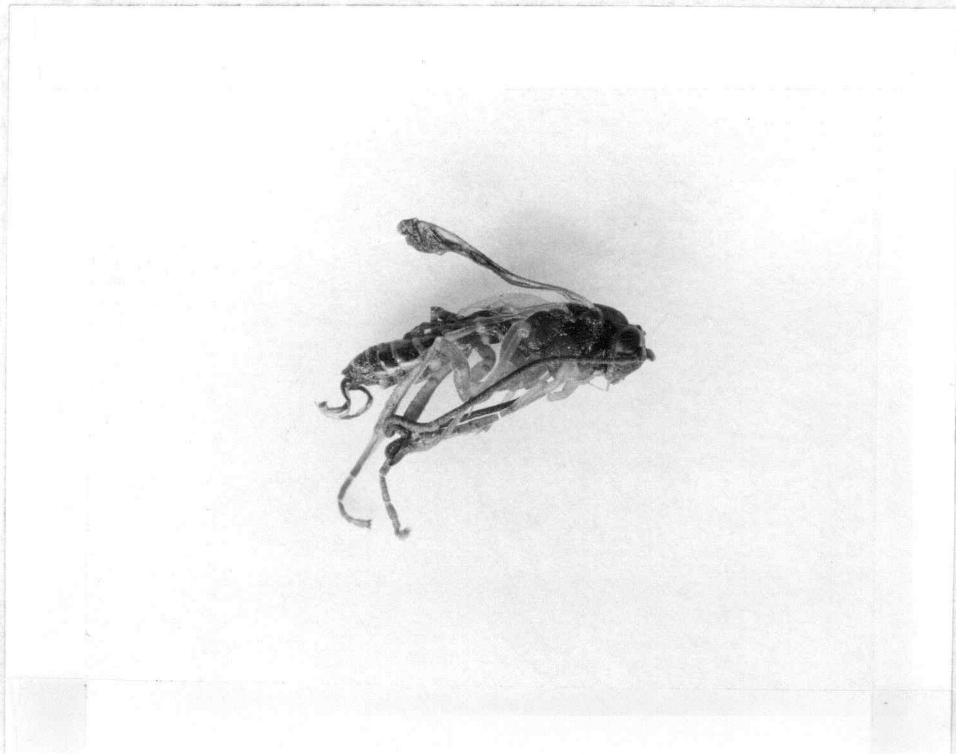

Figure 9. A female Phytocietus burgessi (Cress.) reared from omnivorous leaf tier larva, Canby, Oregon, 1967. (The parasite is misshapen because it died in the cocoon.)

attached to the host by a stalk and most of the larval development occurs after the host spins a cocoon or makes a pupal cell.

The species was described by Cresson (1868) in 1868 and Rohwer (1920) in 1920. The species is known to be distributed from the Atlantic to 100° west in transition (Muesebeck *et al.*, 1951). Thompson (1957, p. 504) recorded the codling moth, omnivorous leaf tier and *Polychrosis liriodendrana* Kearf, as its hosts. Dozier *et al.* (1929) also reported *P. burgessi* parasitized codling moth larvae.

Mesochorus sp.

A single female of *Mesochorus* sp. (Figure 10) was reared from a *C. longana* larva collected at Mt. Angel. This is apparently a hyperparasite of *Enytus eureka*. The adult emerged from its cocoon on June 10, by chewing an exit hole.

According to Clausen (1940) the hyperparasitic habit is strongly developed in the Mesochorini and most frequently encountered genus, *Mesochorus*, attacks the larvae of Braconidae and other Ichneumonidae.

The Relationships of Parasites to Host Plants of Omnivorous Leaf Tier

Parasites of the omnivorous leaf tier have been reared from larvae infesting three species of host plants (Table 10). They were vetch (*Vicia* spp.), false dandelion (*Hypochaeris radicata*) and

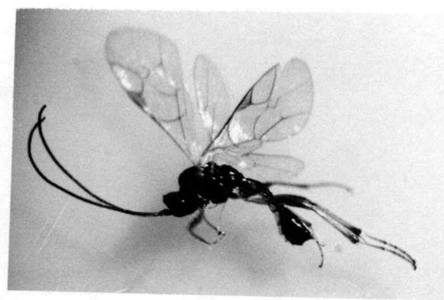

Figure 10. A female Mesochorus sp. (hyperparasite).

Table 10. The relationships of parasites to host plants of omnivorous leaf tier.

Parasites Family and Species	Host plants and percent parasitism Vetch	 False dandelion	 Ox-eye daisy	Locations
Braconidae				
Agathis cincta		1.2[c]		Dallas
			1.0[c]	Marion County
Bracon hyslopi Vier		0.5[c]		Junction City
		2.0[c]		Dallas
			0.4[c]	Scholls
			Abundant[d]	Albany
Bracon gelechiae (Ashm.)		1.0[c]		Junction City
			Abundant[a]	Canby
			15.0[b]	Canby
			Abundant[d]	Albany
Bracon stabilis Wesmael*, [c, f]	Abundant[f]			Mt. Angel[h]
Bracon piger Wesmael*, [c, f]	no comment			Mt. Angel[h]
Eulophidae				
Tetrastichus bruchophagi		0.5[c]		Junction City
Tetrastichus sp.		0.8[c]		Dallas
		0.4[c]		Mt. Angel
			0.4[c]	Salem
Ichneumonidae				
Horogenes eureka (Ashm.)[a, b', e]	17.14[e]			Mt. Angel[e]
Ischnus inquisitorius artriceps (Cress.)			no comment	Albany[d]
Itoplectis conquisitor (Say)	0.36[e]			Mt. Angel
Itoplectis maculator F.[c, *]	no comment			Mt. Angel[h]
Phytodietus burgessi (Cress.)[a, e]	5.88[e]			Canby[e]
Stephanidae				
Chelonus sp.		1.5[c]		Albany

[a] Edwards, W. D., 1936.

[b] Ferguson, G. R., 1938.

[b'] Ferguson, G. R., 1939.

[c] Rosenstiel, R. G., 1957.

[d] Gray, K. (personal communication)

[e] Current research data, 1967.

[f] Ritcher, P. O., 1966.

[g] OSU museum specimens.

[*] Introduced species.

ox-eye daisy (*chrysanthemum* *leucanthemum* var. *pinnatifidum*). Vetch is the most common plant harboring large numbers of host larvae. Six species of parasites presumed to be native have been recorded from larval-infested vetch. Three species of introduced parasites were also reared from omnivorous leaf tier larvae infesting vetch (Table 10). The species *B. stabilis* was found to be abundant (Ritcher, 1966), but the degree of parasitism of the other two species was not cited. During the current study, three species of native omnivorous leaf tier parasites were also reared from infested vetch. They were *Horogenes eureka*, *Phytodietus burgessi* and *Itoplectis conquisitor*. The first two species were also recovered by Edwards (1936) 32 years ago. The degrees of parasitism of those three species observed by the writer during this study were 17.14, 5.88 and 0.36 percent respectively. The *Horogenes eureka* and *Itoplectis conquisitor* were endoparasite while *Phytodietus burgessi* was ectoparasite.

Other workers have also reared parasites from omnivorous leaf tier larvae infesting false dandelion and ox-eye daisy. Four species of parasites were recovered from these two host plants. They were *Agathis cincta*, *Bracon hyslopi*, *Bracon gelechiae* and *Tetrastichus* sp. . *B. hyslopi* and *B. gelechiae* (both ectoparasites) were recorded by Edwards (1936), Ferguson (1938) and Gray (1967). *B. gelechiae* appeared to be more important or at least more abundant.

It was in abundant numbers from the infested ox-eye daisy (Edwards, 1936 and Gray, 1967), but in fewer numbers from false dandelion. Possibly there is relationship between host plants and abundance or extent of parasitism. The two remaining parasite species were not different in degree of parasitism on the two host plants and were less abundant. The percentage of parasitism was less than two perecnt (Rosenstiel, 1957).

Tetrastichus bruchophagi and *Chelonus* sp. were parasites reared only from leaf tier larvae infesting false dandelion. This does not mean that these two species will always attack the host insect feeding on false dandelion, since we have only a single observation (Rosenstiel, 1957). Degree of parasitism of the two species was low. It did not reach two percent (Rosenstiel, 1957).

Ischnus inquisitorius atriceps was reared from infested ox-eye daisy (Gray, 1967). The mode of parasitism and the degree of effectiveness are uncertain.

During the current study, 10 larvae infesting ox-eye daisy were collected near Salem, (Marion County), 10 larvae infesting alfalfa were collected from Mt. Angel and two larvae infesting wild rose were also collected from Mt. Angel. None of these larvae produced parasites.

The Possible Factors Prevented Establishment of Introduced Parasites

It is not unusual that the introduced parasites in question failed to establish. According to Clausen (1952), during a period of 60 years, a total of more than 600 species of parasites and predators were introduced into this country and only approximately 100 of these became established. In Oregon since 1924, 30 species of parasites have been introduced and released in an attempt to control insect pests and only three species are known to be established (Ritcher, 1966). During the current study of omnivorous leaf tier parasites, none of the introduced species were recovered. The factors preventing the establishment of omnivorous leaf tier parasites are not known. In a temperate region such as Oregon, physical factors may be important. Clausen (1952) pointed out that in temperate regions, the introduced parasites may not be able to withstand low temperatures, though these may not be detrimental to the host. For example, 80 percent of Aphytis pupae, a parasite of California red scale, died after exposure to severe winter in California. Also, 100 percent mortality of adult Aphytis was obtained when they were exposed to 30° F. for a day (DeBach et al.,1955). In addition to causing mortality to the insect, low temperatures also sterilize the mated females when exposed to 30° F. for 6 hours. This results in production of males because the sperms in the spermathecae of mated females are killed (DeBach et al., 1955). This might be true in the case of the introduced parasites in question. The three species recovered by Rosenstiel (1957) appeared to be all males (Table 1) with the exception of a single specimen of *Bracon stabilis* which was a female. This might be the result of low temperature sterilization since the minimum winter temperatures of Salem for every year from 1951 to 1957 was below 30° F. (Table 11).

In addition to low temperatures, high temperatures also affect the establishment of parasites. DeBach (1955) demonstrated that 50 percent mortality of adult *Aphytis* resulted from exposure to 90° F. in 20 percent humidity for one day. This is another possible explanation for the failure of introduced parasites in Oregon. The summer climatic conditions of Oregon are hot and dry. The maximum summer temperatures at Salem (Table 11) are usually higher than 90° F. The absence of a suitable alternate host to carry the parasite over winter may also prevent the establishment of parasites (Clausen, 1952).

Table 11. The minimum winter temperatures and the maximum summer temperatures for Salem during 1951-1957.

Years	Min. winter temperatures (°F)	Max. summer temperatures (°F)
1951	16	99
1952	15	102
1953	24	95
1954	18	87
1955	19	100
1956	12	104
1957	11	95

SUMMARY AND CONCLUSIONS

The omnivorous leaf tier [Cnephasia longana (Haw.)] is native to Europe and became a pest of strawberries, Dutch iris, flax, leguminous and cultivated crops of Oregon. One hundred and seven plant species have been recorded as hosts of C. longana in Oregon. Information secured on its life history and habits is reviewed in this paper. Chemical and cultural control have been used to control this pest but gave little promise. The larvae were known to be attacked by several species of insect parasites. Introductions of insect parasites were made from 1951 through 1954 in the hopes that biological control might be successful. Fourteen species of parasites were introduced from France and released in Oregon (Table 1). Of these introduced parasites, three species; B. stabilis, B. piger and I. maculator were recovered by Rosenstiel (1957) in 1955 and again in 1956 with the exception of B. piger. None of them were recovered in 1957 or during this study. In addition to introduced parasites, 14 species of native hymenopterous parasites have been recovered from C. longana in Oregon. The history of parasite recoveries other than introduced species is summarized in Table 2.

The feeding habits of C. longana larvae upon plantain and vetch were observed at Dallas, Oregon. The results of these observations confirm that the first and second instar larvae feed as leaf-miners on plantain. The remaining instars migrate to vetch and other host plants to feed on the tender tips within webbed leaves.

Seasonal populations of C. longana larvae under field conditions were observed in a vetch field near Mt. Angel. The study shows that the stages or instars of larval development were overlapping due to the variation in time of emergence of overwintering larvae.

The emergence of adult moths under field conditions was also observed in the previously mentioned area near Mt. Angel. The moths appeared in the field on June 23 and terminated on August 18. The moth populations reached a peak on June 29. This study confirms that C. longana has one generation a year in the western part of Oregon.

During the current study, three species of hymenopterous parasites and one species of hyperparasite were recovered. They were Enytus eureka (Ash.) [= Horogenes eureka (Ash.)], Itoplectis conquisitor (Say), Phytodietus burgessi (Cress.) and Mesochorus sp.

E. eureka and I. conquisitor are endoparasites while P. burgessi is an ectoparasite. The species E. eureka was found in highest numbers at Mt. Angel. Its parasitism of C. longana was 17.14 percent. This species was also recovered at Oregon City but in smaller numbers. The other two species; I. conquisitor, and P. burgessi, are less important. This is the first record of I. conquisitor occurring in the western United States.

The studies revealed that *E. eureka* attacked the fourth, fifth and sixth instar larvae because none of the earlier instar host larvae produced parasites, and the percentage of parasitism increased during the late larval season. It is possible that seasonal factors may have a definite relationship to host development. The parasites emerged from fifth and sixth instar host larvae.

During this study, all of the parasite species were reared from omnivorous leaf tier larvae on vetch collected from Mt. Angel, Canby and Oregon City.

The emergence of the adult parasite, *E. eureka* and the host insect, *C. longana* under insectary conditions were observed. The parasite started to emerge on June 6 which was nine days earlier than the host. The peak emergence of the parasite was reached on June 18 while the peak emergence of the host was reached on June 28. The last adult parasite emerged on June 28 which was two days earlier than the last host insect's emergence.

The field emergence of adult parasites and the host was also observed. The results failed to show the host-parasite population relationships under field conditions.

The primary objective of this study was to investigate the present status of the 14 species of parasites introduced against the omnivorous leaf tier. Results of this study reveal that none of the introduced parasites are established. The causes of failure of establishment of parasites are not known. Some possible factors preventing the establishment of parasites are suggested by the writer. The physical factors are most important in temperate regions such as Oregon. The low winter temperatures could not only cause death to eggs, pupae and adults of parasites, but may also cause sterilization of mated female parasites.

In temperate regions, the lack of alternate hosts to carry the parasites over winter is another possible factor which could prevent establishment. In addition to low temperatures, hot and dry climatic conditions in the summer in Oregon may be detrimental to the parasites.

Although as many as 14 species of native parasites have been recovered from Oregon, it would appear from this study that none of them has become important as a biological control agent. The species *E. eureka* is the most common parasite recovered, but it attacked the host rather late in the season. Considerable damage to crops had already occurred by the time the parasite emerged.

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