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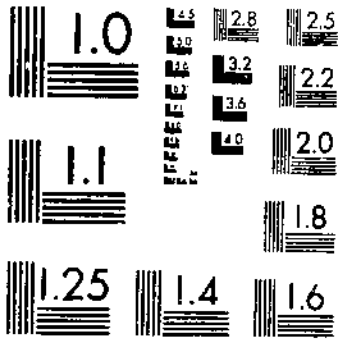
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PARASITES OF THE PECAN NUT CASEBEARER IN TEXAS

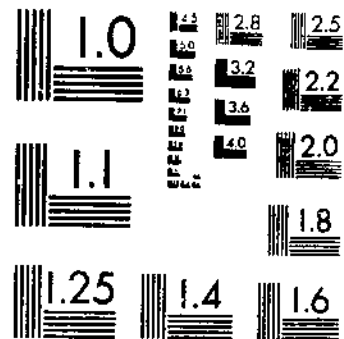
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**UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.**

**Parasites of the Pecan Nut Casebearer
in Texas¹**

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INTRODUCTION

The most curious insect attacking the pecan in Texas is the pecan nut casebearer (*Acrobasis caryae* Grote). Parasitism is an important factor in the natural control of this insect. Because many pecan trees in Texas are inaccessible to spray machines, it was desirable to

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² J. L. Gardiner assisted with this project from September 11, 1930, to April 15, 1931. L. D. Way was employed as a field assistant in the summers of 1929 and 1930, and D. E. Read in the summer of 1930. Parasite specimens were determined by the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, and by the late J. M. Aldrich, Curator of Insects, U. S. National Museum.

obtain all information possible about the parasites of the nut casebearer and to study the possibility of rearing large numbers of the more useful ones for release in control work. Such a study was made in 1920-24. Before these studies were undertaken, 13 species of primary parasites and 2 species of secondary parasites had been reared successfully from *A. caryae*.³

This bulletin gives information on the species of primary and secondary parasites of the nut casebearer that were reared during this period or earlier, as well as on the large-scale production and release of *Trichogramma minutum* Riley and *Perisierala cellularis* var. *punctaticeps* Kieffer.

PARASITES REARED FROM THE NUT CASEBEARER

Thirty-one species of parasites were reared from *Acrobasis caryae*, and their relation to the host was determined:

PRIMARY PARASITES

Hymenoptera:

Bethylidae:

Goniozus foreolatus Ashm.¹

Perisierala cellularis var. *punctaticeps* (Kieffer).¹

Braconidae:

Apanteles epinotiae Vier.¹

Bassus acrobasisidis Cush.

Macrocetrus instabilis Mues

Microbracon variabilis (Prov.).

Orgilus maculiventris (Cress.).

Phaenocarpa tibialis (Fall.).

Chalcididae:

Brachymeria hammani (Cwfd.).¹

Eulophidae:

Dimmockia sp.

Eulophine sp.

Secodella n. sp.

Secodella acrobasis Cwfd.

Secodella subopaca Gahan.

Ichneumonidae:

Angitia sp.

Amblyteles sp.

Calliephialtes grapholithae (Cress.).¹

Cremastus sp.

Hoptoclis conquistator (Say).

Pristomerus curvitychiac Ashm.

Trichogrammatidae:

Trichogramma minutum (Riley).¹

Diptera:

Chloropidae:

Chloropops inquitina (Coq.).

Larvaevoridae:

Zenilla boarminae (Coq.).

Zenilla sp.

Tachinidae:

Nemorilla floralis (Fall.).

Coleoptera:

Cleridae:

Hydnocera knausi (Wickh.).

¹ Also reared from the Hickory shuckworm (*Laspeyresia caryana* (Fitch)).

² A. I. Fahis and H. S. Adair, formerly stationed at the Brownwood, Tex., laboratory, reared these parasites.

PECAN NUT CASEBEARER PARASITES

HYPERPARASITES

Hymenoptera:

Eulophidae:

Secodella n. sp.

Eupelmidae:

Eupelmus amicus (Gir.).

Enrytomidae:

Eurytoma tylodermitis (Ashm.).

Ichneumonidae:

Calliephialtes grapholithae (Cress.).

Perilampidae:

Perilampus fulvicornis (Ashm.).

Nut casebearer larvae were collected from several orchards in central, western, and southern Texas in 1929-34. The records of the parasitization of these larvae are summarized in table 1.

TABLE 1.—Average parasitization of pecan nut casebearer larvae collected in Texas, 1929-34

Year	Overwintering larvae				First generation		Second and third generations	
	In hibernacula		In shoots		Total	Parasitized	Total	Parasitized
	Number	Percent	Number	Percent				
1929	198	25	716	19	663	14		
1930	645	27	1,879	24	695	16		
1931	244	25	1,261	51	3,113	15		
1932	961	11	894	23	3,804	20	1,139	15
1933	908	11	477	16	642	41	666	10
1934			414	8				
1929-34	1,869	11	2,872	21	8,365	31	6,276	15

PRIMARY PARASITES

TRICHOGRAMMA MINUTUM (RILEY)

EFFECTIVENESS

Trichogramma minutum was first recorded as a parasite of the nut casebearer in 1930, when it was found in eggs collected in several orchards near Brownwood, Tex. The number of eggs collected and parasitized were as follows: First generation, 7,684 eggs, parasitization 18 percent; second generation, 1,221 eggs, parasitization 11 percent; and third generation, 927 eggs, parasitization 8 percent. The nut casebearer is usually most numerous in the first generation, and greater numbers of eggs may be found in the first than in the later generations.

DEVELOPMENT IN WINTER

Steps were taken to determine the period required for the development of *Trichogramma*. Two groups of approximately 5,000 eggs of *Sitotroga cerealella* (Oliv.) were exposed in the laboratory to *Trichogramma* for 1 day. The next day the host eggs were transferred to an outdoor weather-instrument shed and the date of emergence of the adult parasites was recorded. The first group of *Sitotroga* eggs was

parasitized on November 11, 1931, and adult parasites emerged 86 days later. In the second group the host eggs were parasitized on February 5, 1932, and adult parasites emerged 42 days later.

FIELD EXPERIMENTS

Approximately 4 million *Trichogramma* parasites were reared in 1930, 1931, and 1932 by the methods described by Hinds and Spencer.⁴ The *Trichogramma* used were collected in Arizona, Georgia, Louisiana, and Texas and were reared in the laboratory on eggs of *Sitotroga cerealella*. All *Trichogramma* were colonized on pecan trees for the control of the nut casebearer. Observations in the laboratory indicated that the parasites from Arizona and Louisiana were more prolific than those from Texas and Georgia. As many as 50,000 parasites per tree were used in some of the tests, but they were ineffective in the control of the casebearer.

SECODELLA ACROBASIS CWF. D.

Secodella acrobasis is a solitary external parasite. It was reared only from nut casebearer larvae that were overwintering in hibernacula. Parasitization of these larvae by *S. acrobasis* averaged 11.3 percent in both 1932 and 1933.

Full-grown larvae of this parasite inside nut casebearer hibernacula were collected early in February. A high percentage of the parasites pupated in March, and the adults emerged during the latter part of March and the first half of April. In 1932 and 1933 nearly all the adults of *Secodella acrobasis* emerged in the first 10 days of April.

The full-grown larva is yellowish green and measures 1.02 mm. in length and 0.39 mm. in width. The simple mandible of the full-grown larva averages 0.03 mm. in length.

APANTLES EPINOTIAE VIER.

EFFECTIVENESS

Apanteles epinotiae (fig. 1) is a solitary, internal parasite of the nut casebearer, and also of the hickory shuckworm (*Laspeyresia caryana* (Fitch)) and *Acrobasis caryivorella* (Rag.). It was thrice reared from larvae of an unidentified lepidopterous insect that feeds on pecan leaves. During the period 1929-34, parasitization of overwintering larvae of the nut casebearer by *A. epinotiae* averaged 2.4 percent, with none in 1929 and a maximum of 7.1 percent in 1930. In 1929-33, parasitization of first-generation larvae was 0.6, 2.0, 6.0, 8.4, and 16.7 percent for the respective years, the average being 6.7 percent. During the same period larvae of the second and later generations were parasitized 1.5, 3.5, 1.4, 0.8, and 2.1 percent, respectively.

Perilampus fulvicornis was reared from *Apanteles epinotiae* larvae that emerged from larvae of all generations of the nut casebearer.

⁴HINDS, W. E., and SPENCER, H. UTILIZATION OF TRICHOGRAMMA MINUTUM FOR CONTROL OF THE SUGARCANE BORER. JOU. ECON. ENT. 21: 273-278, illus. 1928.

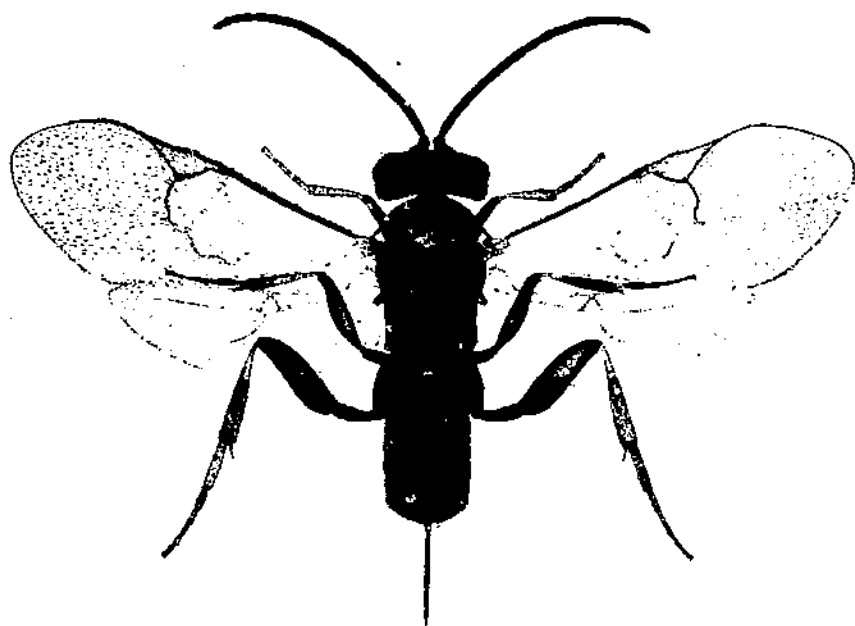


FIGURE 1.—Adult female of *Apanteles epinotiae* $\times 40$.

LIFE HISTORY

Insectary and field records show that *Apanteles epinotiae* overwinters as an immature larva within the body cavity of a larva of the nut casebearer or the hickory shuckworm. Adults of *A. epinotiae* begin to emerge late in March and issue almost continuously until December, no emergence period being interrupted by an interval greater than 2 weeks. Although the adults that emerged in March and December were reared from shuckworm larvae, most of the adults that emerged from April to October were reared from nut casebearer larvae.

Oviposition was observed in cages in the insectary. First- and second-stage nut casebearer larvae were usually attacked in feeding tunnels on the surface of pecan nuts and leaves. The female locates the host larva by prodding her ovipositor through its feeding tunnel. Oviposition causes temporary paralysis of the host larva. After a brief period, however, the host larva becomes active and continues to feed until shortly before the parasite larva emerges. Most of the parasites emerge from fourth-stage nut casebearer larvae. Insectary and field records show that in July and August the period from oviposition to emergence of the parasite larva from its host was about 10 days. Shortly after emerging, the parasite larva spins a closely woven white cocoon in the burrow of the host. In July and August the period required from oviposition to emergence of the adult was about 15 days.

Apanteles epinotiae has more generations in a year than either the nut casebearer or the shuckworm. In the summer both these hosts require two to three times as long for the development of a generation as does this parasite.

The full-grown larva has 14 distinct segments, is white, and measures about 1.7 mm. in length. The mandible has 16 teeth.

BASSUS ACROBASIDIS CUSH.

EFFECTIVENESS

Bassus acrobasis (fig. 2) is a solitary internal parasite of the nut casebearer larva. This parasite was described as a new species by Cushman⁵ from specimens reared by A. I. Fabis and by S. W. Bilsing.

The average parasitization of the overwintering generation of the nut casebearer during the period 1929-34 was 2.5, 1.7, 2.0, 1.3, 2.7, and 0.7 percent for the respective years. Parasitization of first-generation larvae during 1929-33 was 12.2, 5.2, 18.9, 10.8, and 8.9 percent, respectively. In this period the average parasitization of the second and later generations of this host was 1.6 percent.

LIFE HISTORY

Bassus acrobasis overwinters as a first-stage larva within the body of the hibernating nut casebearer larva. The parasite and its host remain inactive during a period usually beginning in September and ending late in March or early in April. The parasite and its host resume their development when the host begins to feed on the pecan buds and shoots. The parasite larvae begin to emerge from their hosts late in April or early in May. The time required for the development of the overwintering generation of *B. acrobasis* in the insectary was 249 to 255 days, or slightly more than 8 months. Adult parasites reared from overwintering hosts usually emerge in May. The life cycle of *B. acrobasis* and that of its host, the nut casebearer, are well synchronized, and each may have two to four generations in a year.

Coupling was observed in 1- by 4-inch shell vials at summer temperatures. Three pairs of *Bassus acrobasis* that emerged in May mated within 24 hours after emergence. Within 2 to 5 days after emerging females in the insectary oviposit in second- or third-stage nut casebearer larvae in vials or cages. The female locates the host larva by prodding her ovipositor through its feeding tunnel. Occasionally a female will deposit an egg in a larva that she has chased from its feeding tunnel. The host larvae is paralyzed for about 1 minute after oviposition. After ovipositing the female leaves the tunnel of the host, but may return to deposit additional eggs in the same larva. Dissections showed that from 1 to 14 eggs were deposited in a single larva. Several parasite eggs may hatch in a single host but only 1 larva will develop to maturity. Since parasite larvae with constrictions near the middle of the body were dissected from nut casebearer larvae, the surviving larvae probably destroyed the other larvae in the host.

A parasitized nut casebearer larva becomes sluggish after it has developed to the fourth or fifth instar, and at that time the parasite larva has nearly completed its development. Many *Bassus acrobasis* larvae fail to mature because they kill their hosts before completing their own development. The last-stage larva usually emerges

⁵ CUSHMAN, R. A. NORTH AMERICAN ICHEUMON-FLIES, NEW AND DESCRIBED, WITH TAXONOMIC AND NOMENCLATORIAL NOTES. U. S. NATL. MUS. PROC. 58: 289-290. 1920.

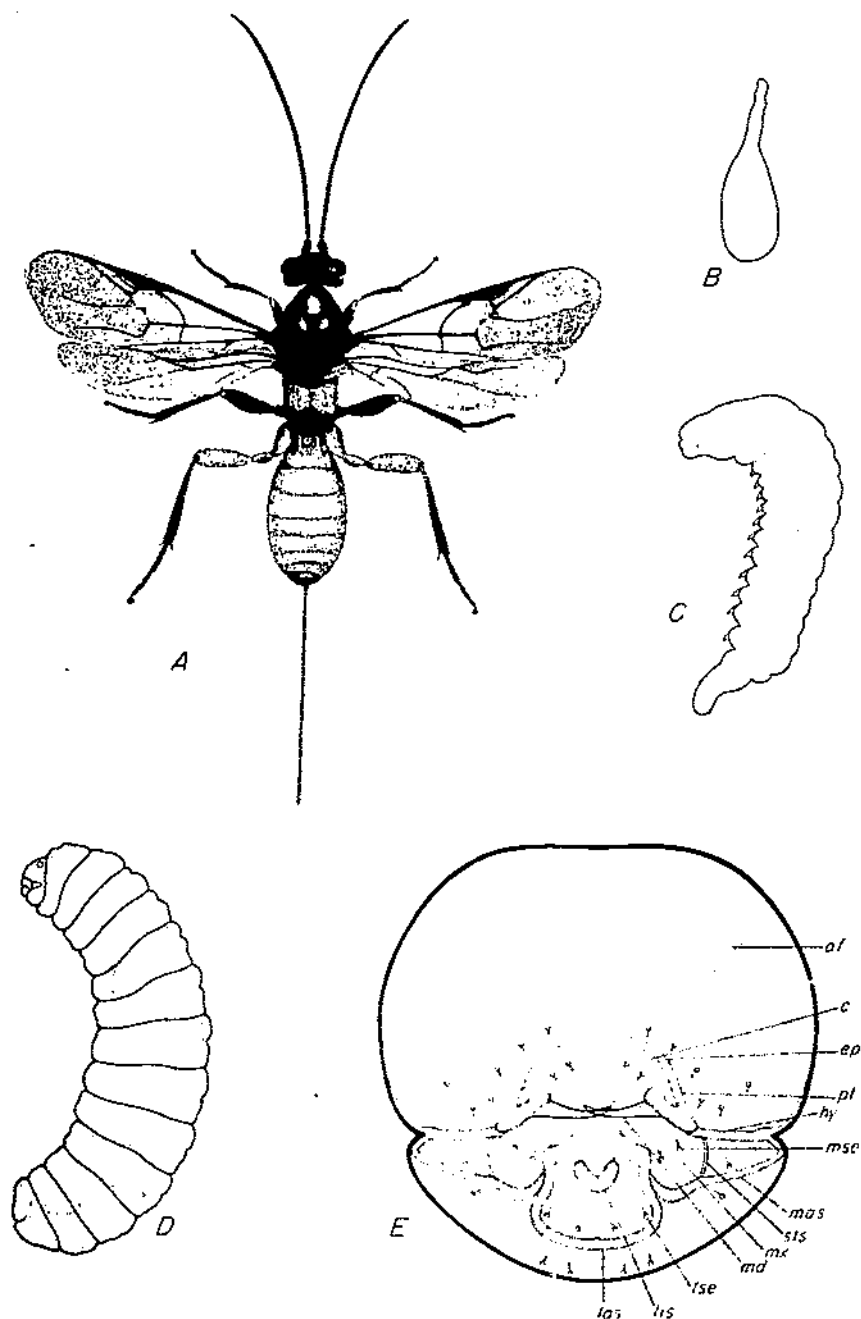


FIGURE 2.—*Bassus acrobasisid*, $\times 14$: A, Adult female; B, egg; C, first-stage larva; D, mature larva; E, head of mature larva: *af*, antennal foramen; *c*, ctypeus; *ep*, epistoma; *hy*, hypostoma; *las*, labio-stipital sclerite; *lis*, ligular sclerite; *lse*, labial setae; *mas*, maxillary sclerite; *md*, mandible; *msc*, maxillary sclerite; *mx*, maxilla; *pl*, pleurostoma; *sis*, stipital sclerite.

laterally through a thoracic segment of a fifth-stage nut casebearer larva. The parasite larva reverses its position and begins to feed externally through the aperture it made in emerging. The parasite usually consumes all of the host except the exoskeleton. Within about 2 days after its emergence the parasite larva completes the spinning of a cocoon.

A total of 86 adults of *Bassus acrobasis* were bred on insectary-reared nut casebearer larvae, and the data were supplemented with a much larger number of records from field-collected material. The period from the deposition of the egg to the emergence of the larva from its host was 17 to 18 days during July, August, and September. From oviposition to the emergence of the adult in June and July, the males required 31 to 34 days and the females 34 to 36 days. In a total of 144 adults reared from host larvae parasitized in the orchard, 79 were females and 65 were males.

The newly laid egg (fig. 2, *B*) is flask-shaped and broadly rounded at the cephalic end. It is approximately the same width for about two-thirds of its length, and then tapers to form the long narrow caudal extremity. The egg is translucent white and its surface is smooth. Its average length is 0.14 mm.; its greatest width, 0.04 mm.

The translucent, white first-stage larva (fig. 2, *C*) consists of a head and 13 body segments. Its length averages 0.66 mm. The head is somewhat flattened. It measures 0.15 mm. across the widest part of the base and tapers slightly to a bluntly rounded front. The mandibles are narrow, curved, and sharply pointed, with an average length of 0.05 mm. They are widely separated at their bases, are heavily sclerotized, and may be easily observed in a live larva.

The last-stage larva (fig. 2, *D*) consists of a head (fig. 2, *E*) and 13 body segments. The average length of the full-fed larva is 6.07 mm. and its greatest width is 2.08 mm. The larva, shortly after emerging from its host, is nearly cylindrical and usually greenish white. After feeding externally on the remains of the host, the color of the larva gradually changes to yellow, with only a slight tinge of green remaining. The color of the alimentary tract is reddish brown during the later stages of larval development. In the full-fed larva a pronounced lateral fold extends from the first to the ninth abdominal segment. The mandible measures 0.16 mm. in length and has approximately 21 teeth.

The cocoon is oval and glossy white.

MACROCENTRUS INSTABILIS MUES.

EFFECTIVENESS

Macrocentrus instabilis is a solitary internal parasite of the pecan nut casebearer. According to Muesebeck,⁶ this parasite has been bred from *Grapholitha molesta* (Busck), *Laspeyresia juncebrana* (Treat.), *Coleophora malivorella* Riley, and *Aerobasis caryivorella* (Rag.).

Field parasitization of overwintering-generation nut case bearer larvae by *Macrocentrus instabilis* in the period 1929-34 was 0, 3.3, 0.4, 1.6, 2.9, and 0.7 percent for the respective years, averaging 1.48 percent. Parasitization of the first-generation larvae for the years 1929-

⁶MUESEBECK, C. F. W. REVISION OF THE NEARCTIC ICHNEUMON FLIES BELONGING TO THE GENUS MACROCENTRUS. U. S. Natl. Mus. Proc. 80 (art. 23): 1-55. 1932.

33 was 2.1, 0.2, 1.7, 2.0, and 6.7 percent, respectively, averaging 4.3 percent. The parasitization of second- and later-generation larvae in this period was 2.4, 2.7, 2.0, 6.1, and 0.9 percent, respectively, averaging 2.8 percent.

LIFE HISTORY

Macrocentrus instabilis overwinters as an immature larva within the body of a hibernating nut casebearer larva. This parasite and the nut casebearer have the same number of generations in a year. In a total of 245 adults reared from host larvae parasitized in the orchard 142 were females and 103 were males.

Coupling was observed in 1- by 4-inch shell vials in the insectary in June. Mating may occur within 1 day after emergence. Second- or third-stage nut casebearer larvae are usually selected for oviposition. During the summer months the incubation of the egg and the development of the larva within its host required about 21 days. The full-grown parasite larva may emerge from a fifth-stage larva or a pupa. The larva spins a cocoon within 2 days after emerging from its host. An average of 11 days elapsed between the date of the spinning of a cocoon and the emergence of the adult. In July and August the period from oviposition to emergence of the adult was 28 to 36 days. Females required 1 to 3 days longer for development than males.

MICROBRACON VARIABILIS (PROV.)

PARASITIZATION OF OVERWINTERING LARVAE

In Texas *Microbracon variabilis* (fig. 3) is the most important parasite of the overwintering larvae of the nut casebearer in April and May. Parasitization of overwintering larvae by *M. variabilis* in 1929-34 was 12.1, 6.4, 14.3, 15.8, 5.7, and 1.5 percent in the respective years. The parasitization of first-generation larvae in 1929-33 was 2.0, 1.2, 5.7, 1.8, and 1.9 percent, respectively. Parasitization of second- and later-generation larvae in this period was 0.6, 0.8, 0.6, 0.2, and 0.3 percent, respectively.

Records of 305 adults of *Microbracon variabilis* reared from every generation of the nut casebearer showed that females were slightly more numerous than males. Two females that emerged on August 13, 1935, were fed honey solution and confined in cellophane cages. One lived 63 and the other 82 days.

LIFE HISTORY

In Texas *Microbracon variabilis* overwinters as a full-grown larva. A period of 7 to 12 months is required for the development of the overwintering generation, the length of this period being influenced by the generation of the host. The larvae overwintering in the host pupate in March and adults emerge in April. Nearly all the overwintering larvae were reared from first-generation nut casebearer larvae, although a few were reared from every generation of this host. Approximately one-third of the *M. variabilis* larvae collected in the orchard between April and September pupated in the following March. Summer- and winter-form larvae may or may not develop on a single host larva. Records of host larvae parasitized by *M. variabilis* in the orchard in 1931 showed the numbers of larvae from

which adults were reared in 1931 and 1932. From 84 larvae within the host, adults emerged in 1931; from 23 larvae within the host, adults emerged in 1932; and from 15 larvae within the host, adults emerged in 1931 and 1932.

Oviposition is most frequent on fifth-, fourth-, and third-stage nut casebearer larvae in the order named. The female paralyzes the host larva and deposits from 1 to 18 eggs externally. Usually 4 or 5 eggs

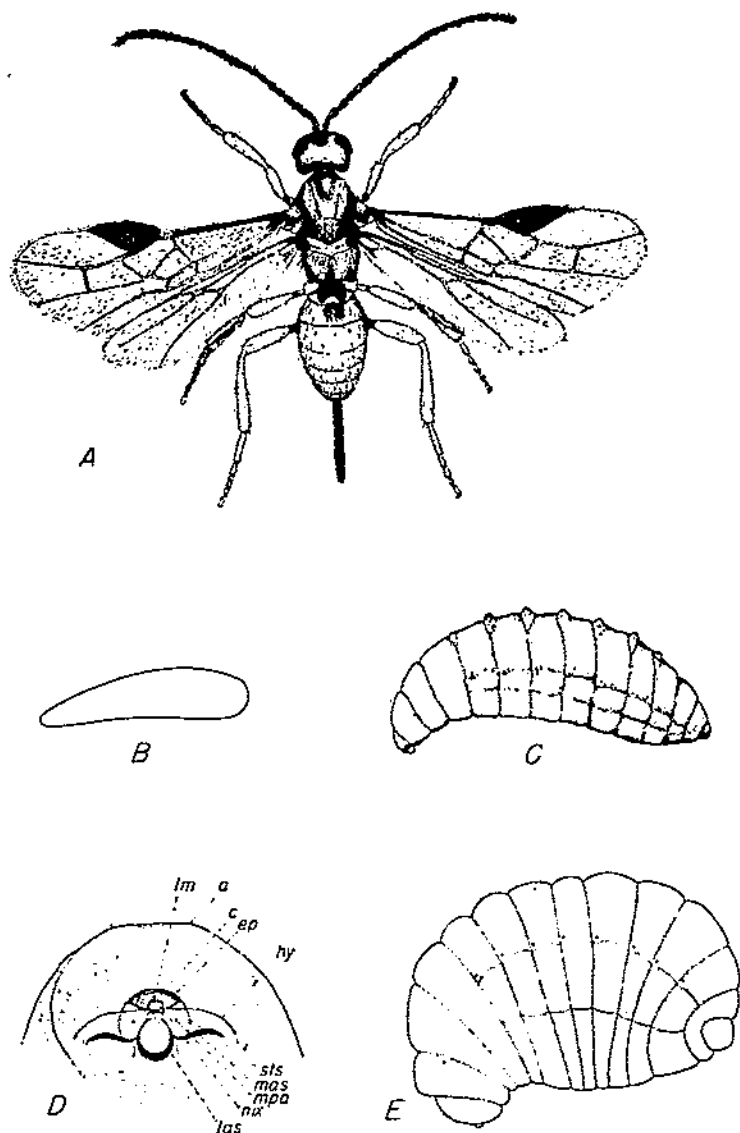


FIGURE 3.—*Microbracon variabilis*: A, Adult female; B, egg; C, macare summer-form larva; D, head of mature, summer-form—*a*, antenna; *c*, clypeus; *ep*, epistoma; *hy*, hypostoma; *las*, labiostipital sclerome; *lm*, labrum; *mas*, maxillary palpus; *mpa*, maxilla; *sts*, stipital sclerome; E, mature overwintering larva.

are deposited on an overwintering-generation larva and 2 or 3 eggs on the larvae of other generations of this host. In the latter half of April and the first half of May 1935, 20 *Microbracon variabilis* were reared in cellophane cages. The incubation period for the eggs was 4 to 5 days. The larvae fed on the host 4 to 5 days. The periods required for the hatching of the eggs and the feeding of the larvae on the host were the same for the overwintering and the summer form of this parasite. Usually the larva fed at more than one position on the host. After leaving the host the larvae completed the spinning of cocoons within 1 day. The prepupal period began about 3 days after the larvae left the host. The duration of the prepupal period was 1 to 2 days and the pupal period 6 days. The period from the deposition of the egg to the emergence of the adult was 19 to 23 days. Adults of the summer form of *M. variabilis* emerged during the months April to September, inclusive.

The egg (fig. 3, B) is near-white in color, somewhat translucent, oblong-ovate in form, slightly curved, and widest near the cephalic end. The surface of the chorion is smooth. It measures 0.69 mm. in length by 0.17 mm. in width at the greatest diameter.

The newly hatched summer-form larva measures 0.53 mm. in length. The body, exclusive of the head, has 13 segments. Immediately after hatching the larva is white, but after feeding it usually becomes light brown. The head is slightly sclerotized. The mandible averages 0.03 mm. in length and 0.02 mm. in width, and it has three teeth. Many small setae extend dorsally across the thoracic and abdominal segments. Three lateral setae are near the center of the thoracic and the first to eighth abdominal segments. The overwintering form of primary larva is shorter in proportion to width than the summer form.

The smallest second-stage summer-form larva observed was 1.18 mm. long and the largest 2.30 mm. The head is lightly sclerotized. The mandible has five teeth. It averages 0.04 mm. in length and 0.03 mm. in width. The position of the lateral setae are the same as on the primary larvae.

The full-grown summer-form larva (fig. 3, C) is 3.62 mm. in length and 1.42 mm. in width, and its head is 0.34 mm. wide. When viewed dorsally the larva appears elliptical in outline. Laterally it appears crescent-shaped, and a lateral fold extends from the first through the ninth abdominal segment, where it becomes almost imperceptible. A small dorsal hump is present on the second to seventh abdominal segments. The third, fourth, and fifth abdominal segments are the widest parts of the larva. Immediately after leaving the host, the cuticular color is light yellow, but the contents of the alimentary canal make the larva look light reddish brown. After excretion, prior to transformation to the prepupal stage, the larva becomes light yellow. One long lateral seta is near the center of the thoracic segments and all the abdominal segments except the last. Four large external setae were observed laterally on the tenth abdominal segment. Numerous small setae, which could be observed only under high magnification, covered the integument on the thoracic and abdominal segments. One open spiracle was observed on the first thoracic segment and on the first to eighth abdominal segments. The mandible has six to eight teeth. More than half of those examined had seven teeth. The mandible is 0.06 mm. long and 0.01 mm. wide. The

head and mouth-parts of a live full-grown larva are shown in figure 3, *D*.

The full-grown overwintering larvae (fig. 3, *E*) is 2.12 mm. long and 1.39 mm. wide. Open spiracles were observed on the first thoracic and on the first to the eighth abdominal segments. The thoracic and abdominal segments are covered with numerous small setae. A row of large lateral setae are present on all the body segments, except the tenth abdominal, which has four large external lateral setae. Many large groups of fat bodies were observed on the abdominal segments. The head is heavily sclerotized. The mandible has seven teeth. Full-grown summer and overwintering larvae are readily separated by comparing the proportion between the length and width of the body. The full-grown summer-form larva is approximately $2\frac{1}{2}$ times as long as wide, and the overwintering larva is about $1\frac{1}{2}$ times as long as wide.

All the larvae that develop on a host are usually included in one group cocoon in the burrow of the host. The cocoons are extremely variable in size, shape, and arrangement, and are usually either light or dark brown.

ORGILUS MACULIVENTRIS (CRESS.)

Orgilus maculiventris is a solitary internal parasite of the larva of the nut casebearer. It was reared from overwintering first-, second-, and third-generation larvae in the period 1929-31. The parasitization never exceeded 1 percent.

The egg of *Orgilus maculiventris* is elongate and curved, tapering from a rounded cephalic pole to a sharply pointed caudal pole. The egg is 0.53 mm. long and its greatest width is 0.10 mm. Under insectary conditions 1 female deposited 21 eggs in a first-stage nut casebearer larva. Small larvae that have been attacked by this parasite feed until they develop to the fourth or fifth stage; then the full-grown parasite larva emerges and forms a cocoon. *Orgilus maculiventris* and its host have the same number of generations in a year. The parasite overwinters as an immature larva within the body of a hibernating nut casebearer larva.

CALLIEPHIALTES GRAPHOLITHAE (CRESS.)

PRIMARY AND SECONDARY PARASITE

Calliephialtes grapholithae (fig. 4) has been reared as a primary parasite from the nut casebearer, the leaf casebearer, and the shuckworm, and as a secondary parasite from *Bassus acrobasisidis* Cush.

The extent of parasitization of the nut casebearer by *Calliephialtes grapholithae* varied greatly in different seasons. In 1931 a total of 1,264 first-generation nut casebearer larvae were collected, and 2.7 percent of these larvae were attacked by this parasite. In other collections of this host the parasitization was less than 1 percent. *C. grapholithae* was reared from the overwintering, first, second, and third generations of the nut casebearer.

The records obtained in this study indicate that *Calliephialtes grapholithae* may breed in warm periods during the winter in central Texas on shuckworm larvae and possibly on other hosts. In January and February larvae, prepupae, and pupae of this parasite were found

in burrows of the shuckworm. From the pupae collected early in February adults emerged late in March.

LIFE HISTORY

Mating was observed in glass vials exposed to direct sunlight. The precoviposition period was 14 to 17 days in September. Oviposition was most frequent on fifth- and fourth-stage nut casebearer larvae, in the order named. Fresh frass over the entrance to the burrow apparently aids *Calliephialtes grapholithae* in locating the host larva. An artificial oviposition chamber was designed for confining the host larvae. It consisted of a wood board $3\frac{1}{2}$ inches long, 1 inch wide, and 1 inch thick. Two cavities, each $\frac{3}{4}$ inch long, $\frac{1}{4}$ inch wide, and $\frac{1}{4}$ inch deep, were cut in the board for confining two host larvae. Screen wire covered with fresh frass from nut casebearer larvae was placed over these cavities. One egg was usually deposited on or near the paralyzed host larva. The egg is not attached to the host with an adhesive. In the insectary 4 females deposited 144 eggs. One 40-day-old female was accidentally filled after she had deposited 65 eggs. Another lived 39 days and deposited 62 eggs. Three females deposited an average of 2 eggs per day during the oviposition period.

In the latter half of August and the first half of September, incubation required approximately $11\frac{1}{2}$ days. The larva usually feeds at three to five different positions on its host. In August and September the larval feeding period was 3 days. The larva spins a cocoon within 1 to 2 days after leaving its host. In September the prepupal period was approximately 1 day and the pupal period $7\frac{1}{2}$ days. The period from the deposition of the egg to the emergence of the adult was 16 days in September and $18\frac{1}{2}$ days in October.

The newly laid egg is white, quasicylindrical in form, slightly curved, and pointed at both ends. The chorion is covered with many microscopic tubercles. The average length of the egg is 1.85 mm., and the width 0.32 mm. After the egg has been incubated about 15 hours it becomes more curved in outline and light yellow in color.

The larva of *Calliephialtes grapholithae* passes through five stages. A newly hatched larva is nearly colorless, but after it has fed all of the body except the head and anal segment may become light green.

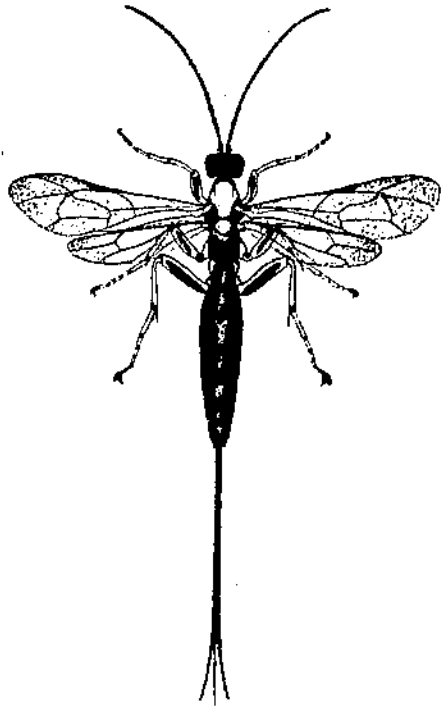


FIGURE 4.—Adult female of *Calliephialtes grapholithae*.

The larva measures about 1.42 mm. in length and 0.30 mm. in width. Segmentation is faint but definite. One large seta is borne laterally on each of the thoracic and abdominal segments. The head measures 0.24 mm. in width. Four large setae are present between the rudimentary antennae.

Fourth-stage larvae differ greatly from those of the preceding stages. A pronounced lateral fold extends from the second thoracic segment through the eighth abdominal segment. Open spiracles were observed on the first thoracic and on the first to eighth abdominal segments. The head is heavily sclerotized and the simple mandible is about 0.09 mm. long and 0.06 mm. wide.

The fifth-stage larva is about 6.34 mm. long and 1.87 mm. wide. The lateral fold is similar, but heavier than in the preceding stage. One large ventral spine is found near the middle of the thoracic segment and one on each of the first to the eighth abdominal segments, inclusive. The thoracic and first to ninth abdominal segments are each circumscribed with 20 setae. The head is 0.67 mm. wide and is roughly heart-shaped. The mandible is simple and measures 0.11 mm. in length and 0.07 mm. in width.

PERISIEROLA CELLULARIS VAR. PUNCTATICEPS (KIEFFER)

EFFECTIVENESS

Perisierola cellularis var. *punctaticeps* (figs. 5, 6) is an external parasite of the nut casebearer larva and also of *Aerobasis caryivorella* and the shuckworm. During the period 1929-32 the average parasitization of overwintering-generation nut casebearer larvae by *Perisierola* was 0.6, 4.5, 0, and 0.5 percent for the respective years. Parasitization of first-generation nut casebearer larvae by this species in 1929-33 was 5.0, 3.4, 2.8, and 6.4 percent, respectively. During the period 1929-31 the average parasitization of the second and third generation nut casebearer larvae was 9.4, 7.0, and 1.1 percent, respectively. *Perisierola* frequently parasitizes shuckworm larvae that are feeding inside Phylloxera galls, but seems to have difficulty in attacking shuckworm larvae when feeding inside pecan shucks.

In a total of 465 adults reared from nut casebearer larvae collected in the orchard, 78 percent were females and 22 percent were males. Both sexes were reared from approximately 50 percent of the host larvae collected in the orchard.

LIFE HISTORY

In central Texas *Perisierola* probably overwinters as an adult. Fertilized females in glass vials, placed outdoors in December 1930 and January 1931, lived 25 to 135 days. On February 24, 1930, 7 females deposited eggs on an equal number of hosts, and a total of 22 adults emerged 43 to 46 days later.

Mating may take place in glass vials or gelatin capsules when the room temperature is above 70° F. Females were fertilized within 1 hour and as long as 3 weeks after emergence. During February and March 1930, 10 unmated females were supplied with host larvae at frequent intervals throughout their lives. All their progeny were males.

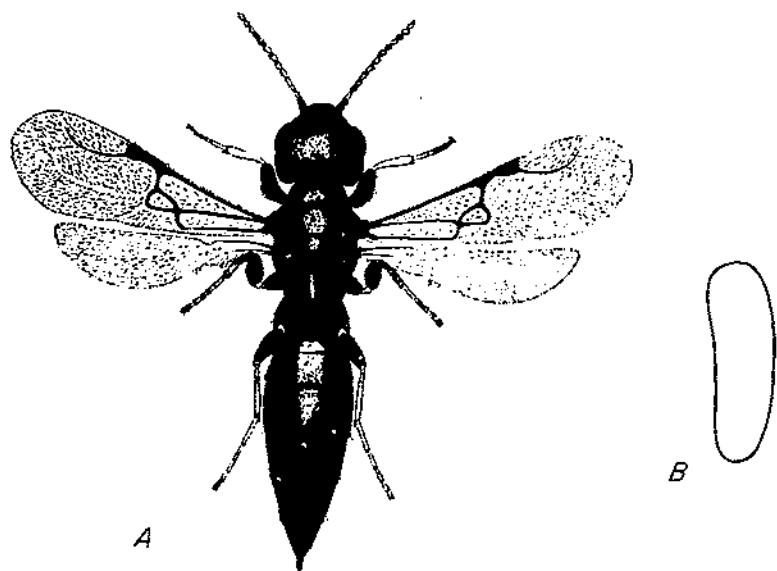


FIGURE 5.—*Perisicrola cellularis punctaticeps*: A, Adult female; B, egg.

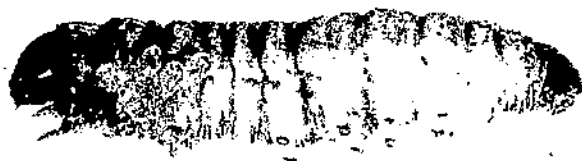


FIGURE 6.—*Perisicrola cellularis* var. *punctaticeps*, first-stage larva feeding on nut casebearer larva.

Females cut one or more holes in a cocoon before attacking the host. The female usually stings the host larva on the ventral side of a thoracic segment. The host larva was usually stung from one to four times prior to oviposition, which followed within $\frac{1}{2}$ hour to 3 hours. A nut casebearer larva usually attempts to bite the attacking female. It was frequently observed that a nut casebearer larva was able to injure the attacking female so seriously that death followed within a few hours. Shuckworm larvae rarely if ever injured the attacking female, because the host larva was unable to move actively after being paralyzed by *Perisicrola* and always died. Many of the paralyzed host larvae were not used for oviposition.

Eggs may be deposited on almost any portion of the abdominal or thoracic segments of the host larva, but most of the eggs were lying flat on the dorsum of the abdominal segments. A high percentage

were placed longitudinally on the host's body. From 1 to 18 eggs may be deposited on a nut casebearer larva, but in the orchard 5 eggs were usually deposited on a fourth- or fifth-stage larva. Eggs were examined under transmitted light to determine the progress of incubation. The first evidence of hatching was the beginning of successive contractions of the digestive organs in feeding. In hatching, the eggshell splits dorsally and is worked around under the ventral side of the larva's body. During the warm periods in February 1930, eggs were deposited on four hosts, but subsequent low temperatures prevented them from hatching. From 9 to 52 females were confined in glass vials with shuckworm larvae from December 18, 1930, to March 30, 1931, and no eggs were deposited on any of the hosts. Records on the hatching of 300 *Perisierola* eggs in March and April 1930 in an outdoor insectary showed a minimum incubation period of 2 days and a maximum of 8 days. During June, July, and August approximately $1\frac{1}{2}$ days were required for incubation. In that period the interval between egg deposition and the emergence of the adult was approximately 11 days.

Both first- and second-stage larvae lie flat on the host larva. The last-stage larva cuts inside the body of the host. The head and thorax of the parasite larva are imbedded in the host, and the head changes from a longitudinal to a transverse position on the host. When more than four larvae develop on one host all of the body contents may be consumed except the integument, the head, and the legs.

In February and March 1930, 76 females were used in obtaining life-history data at a controlled temperature of 80°-85° F. Each female was placed in a gelatin capsule with a larva of the shuckworm. The minimum preoviposition period was 3 days, the average 5.7 days, the maximum 23 days. The average period from emergence to the cessation of oviposition was 24.8 days and the maximum was 44 days. The number of eggs deposited by the average female was 34.3 and the maximum was 104. The longevity of the average female was 30.7 days and the maximum 54 days. Records were obtained on the duration of the feeding period of 545 larvae on 109 hosts. The duration of the larval feeding period was 2 to 3 days; the cocooning period required $1\frac{1}{2}$ to 2 days; the prepupal period required 1 day; and the duration of the pupal period averaged $4\frac{1}{2}$ days. The period from egg deposition to the emergence of the adult was approximately 11 days.

The egg (fig. 5, B) is oblong, ovate, nearly cylindrical, slightly curved, and tapers gradually from the cephalic end to the caudal extremity. On the surface it is mucilaginous, somewhat translucent, and shiny shortly after deposition. The egg appears to be white when viewed on the host, and dirty-white when examined by transmitted light. The surface of the chorion is smooth. The average dimensions of 10 eggs were 0.68 mm. in length by 0.22 mm. in width at the greatest diameter.

The number of larval stages was not determined. Descriptions of the first, second, and mature larval stages were prepared.

The appearance of the first-stage larva (fig. 6) immediately after hatching is similar to that of the egg. At the beginning of this stage the larva is partially translucent, dirty-white, and slightly smaller than the egg from which it hatched. Within 3 hours after hatching a variable number of slightly sunken transverse lines appear

dorsally and laterally on the larva. After the larva has fed approximately 7 hours its width at the center of its body is nearly one-half its length. The tracheal system consists of a longitudinal trunk and seven pairs of open spiracles on each side of the body. The fully developed first-stage larva is 0.68 to 0.78 mm. long; its greatest width is 0.33 mm. It is devoid of spines, tubercles, and segmentary appendages. No external abdominal sutures were observed. The predominating color of the abdominal region of larvae that have fed on nut casebearer larvae is light green, whereas the color of those that develop on shuckworm larvae is light yellow. The thorax and head are dirty white. The head measures approximately 0.12 mm. in width and 0.14 mm. in length. The mandibles are nearly straight, lightly sclerotized, and 0.02 mm. long.

The fully developed second-stage larva is 1.5 mm. long and 0.68 mm. wide. No external spines, tubercles, or segmentary appendages were observed. The head is lightly sclerotized, nearly circular in outline, 0.25 mm. long, and 0.23 mm. wide. The position of the head is somewhat cephalad, as compared with its ventral position in the preceding stage. The mandibles are lightly sclerotized, curved, and 0.03 mm. long. The tracheal system consists of a longitudinal trunk and nine open spiracles on each side of the body.

The full-grown larva consists of a head and 13 body segments. It is approximately 3.71 mm. long and 1.16 mm. wide. The sutures between the head and the thorax, and between the thoracic and the last two abdominal segments encircle the body. The differentiation of the intervening abdominal segments is indicated only by ventral sutures extending nearly to the lateral fold. A pronounced lateral fold extends from the second to the ninth abdominal segment. One pair of setae is present dorsally on each abdominal segment. The respiratory system consists of a longitudinal trunk and 10 open spiracles on each side of the body. Fully 200 groups of fat cells are distributed over all portions of the abdomen.

The head is heavily sclerotized. It is approximately hemispherical in form. The mandibles have six heavily sclerotized teeth on the posterior edge.

Each larva spins a separate, loosely woven cocoon inside the burrow of the host. The cocoons are light brown when the host is the nut casebearer and white when the host is the shuckworm.

LABORATORY EXPERIMENTS

Between January 1 and April 15, 1930, more than 25,000 adults of *Perisierola* were reared on shuckworm larvae in the laboratory. All operations in the propagation of the parasite, except the storage of hosts prior to oviposition, were conducted in a room maintained at a temperature of 80° to 85° F. Females were mated by confining five females and one male in a capsule for 3 days. Oviposition was effected by confining one gravid female with one host larva in a capsule for 3 days. All hosts parasitized in each 3-day period were segregated in lots, to save labor in handling the parasites. The principal difficulty in the propagation of *Perisierola* in the spring was that a high percentage of the host larvae collected during this season in the orchard were infested with nearly full-grown larvae of the parasite *Phanerotoma fasciata* (Prov.). This difficulty was

largely eliminated by placing the shuckworm larvae in storage in November at a temperature of 35° to 40° F., to check further development of the *Phanerotoma* larvae.

AMBLYTELES SP.

One male *Amblyteles* sp. emerged from a first-generation nut casebearer pupa in May 1931.

ANGITIA SP.

Angitia sp. was reared only from overwintering-generation larvae of the nut casebearer. All the adult parasites emerged in April or May. *Angitia* is an internal solitary parasite which overwinters in the body of hibernating nut casebearer larvae. Parasitization of overwintering-generation larvae of the nut casebearer by *Angitia* during the period 1929-34 was 3.0, 0.25, 2.6, 0.4, and 0 percent for the respective years, with an average parasitization of 1.4 percent.

BRACHYMERIA HAMMARI (CWFED.)

Brachymeria hammari is a solitary internal parasite of the nut casebearer and also of the pecan leaf casebearer and the shuckworm. This parasite has been reared from the overwintering, first, and second generations of the nut casebearer. Five specimens of *B. hammari* were bred in 1930 from 4,757 larvae and pupae of the nut casebearer. Each parasite reared from the nut casebearer formed a pupation cell within the pupal skin of the host. In May the length of the pupal period was 14 days and in July it was 7 days.

CREMASTUS SP.

Four specimens of this ichneumonid were reared from nut casebearer larvae collected in June and July in 1931 and 1932.

DIMMOCKIA SP.

On May 2, 1930, a fifth-stage nut casebearer larvae was collected on which seven larvae of *Dimmockia* sp. were feeding externally. The parasite larvae pupated in the burrow of their host without spinning cocoons. Adult parasites emerged 20 days after the date of collection of the host larvae.

EULOPHINE SP.

A single specimen of a species of *Eulophine* was reared by A. I. Fabis from a nut casebearer larva collected in June 1918.

GONIOZUS FOVEOLATUS (BRUES.)

Goniozus foveolatus was thrice reared from nut casebearer larvae in August 1927 by H. S. Adair, who also obtained specimens of this parasite from mass cages containing larvae of the nut casebearer on eight dates in June and July 1927. The writers reared *G. foveolatus* from two nut casebearer larvae and from one shuckworm larva in July 1931. Two specimens of this parasite were reared from *Acrobasis caryivorella* in July 1935.

ITOPLECTIS CONQUISITOR (SAY)

A. I. Fabis reared 19 specimens of *Itoplectis conquisitor* from *Acrobasis* pupae in May of 1918 and 1919. The writers reared four specimens of this parasite from nut casebearer pupae collected in May 1930.

PHANEROTOMA TIBIALIS (HALD.)

Phanerotoma tibialis was thrice reared from fourth-stage nut casebearer larvae collected in April and June 1930. Three adults of this parasite were bred from *Acrobasis caryivorella* in July 1935. A closely related species, *P. fasciata* (Prov.), is the most important parasite of the shuckworm in Texas.

PRISTOMERUS EURYPHYCHIAE CRESS.

Twelve specimens of *Pristomerus euryptychiae* were reared from nut casebearer larvae and pupae collected in June, July, and August in 1930, 1931, and 1933.

SECODELLA N. SP.

Secodella n. sp. was reared as a primary parasite from eight nut casebearer larvae, including all generations of this host. The larva pupates in the burrow of its host without spinning a cocoon. Larvae collected in May emerged as adults 17 to 24 days later. *Secodella* n. sp. is also a secondary parasite.

SECODELLA SUBOPACA GAHAN

During the period 1929-33 four specimens of *Secodella subopaca* were reared in May, June, and August as a primary parasite of the nut casebearer.

CHAEFOCHLOROPS INQUILINA (COQ.)

Two flies were reared from a fifth-stage nut casebearer larva collected in September 1930. The adult emerged from puparia inside the host larva.

ZENILLIA BOARMIAE (COQ.)

A. I. Fabis reared three flies from nut casebearer pupae in July 1919.

ZENILLIA SP.

A. I. Fabis reared one fly from a nut casebearer pupa in 1919.

NEMORILLA FLORALIS (FALL.)

Nemorilla floralis is a minor parasite of the nut casebearer in Texas, only 18 flies having been reared from the larvae and pupae of this host collected in the period 1929-31. Most of the flies were reared from the overwintering generation of the nut casebearer, although every generation of this host was parasitized by *N. floralis*.

The egg of *Nemorilla floralis* is usually deposited externally on either a thoracic segment or the head of the host larva. A few eggs deposited on the head did not result in parasitization, apparently because the parasite larva after hatching was unable to penetrate the

tough cuticula. The parasite larva usually formed a puparium inside the host pupa.

HYDROCERA KNAUSI WICKII.

During the period 1929-34 five adults of *Hydnocera knausi* were reared from nut casebearer larvae and four adults were obtained from mass cages containing nuts infested by this host. One specimen of *H. knausi* was reared from a shuckworm larva and one adult of *H. sp.* was reared from the shuckworm in 1931. Observations showed that *H. knausi* is an internal parasite and that its larva feeds externally after emerging from the host. In 1931 one *H. knausi* overwintered as an immature larva within the body of a hibernating nut casebearer larva.

HYPERPARASITES

SECODELLA N. SP.

Twice in May 1932 and once in May 1934 *Secodella n. sp.* was reared as a secondary parasite from *Microbracon variabilis* and this species was also reared as a primary parasite of the nut casebearer.

EUPELMUS AMICUS GIR.

Thirty-three specimens of *Eupelmus amicus* were reared from primary parasites of the nut casebearer during the period 1931-33. Adults emerged in every month from May to September, inclusive, with 21 emerging in July. Only females of this secondary parasite were reared. Larvae of *E. amicus* were observed feeding externally on larvae of *Bassus acrobasis* and *Microbracon variabilis*. The numbers of *E. amicus* reared from parasites of the nut casebearer were as follows: *Bassus acrobasis*, 13; *Brachymeria hammoni*, 1; *Calliephialtes grapholithae*, 1; *Macrocentrus instabilis*, 2; *Microbracon variabilis*, 7; and *Perisicula cellularis* var. *punctaticeps*, 1.

EURYTOMA TYLODERMATIS ASHM.

During the period 1929-33 *Eurytoma tylodermatis* was thrice reared from *Microbracon variabilis* and once each from *Macrocentrus instabilis* and *Bassus acrobasis*. Adults of *E. tylodermatis* emerged in May, June, and July.

CALLIEPHIALTES GRAPHOLITHAE (CRESS.)

Twice in May 1930, and four times in July 1931, males of *Calliephialtes grapholithae* were reared as secondary parasites from *Bassus acrobasis*, a primary parasite of the nut casebearer. *C. grapholithae* has been reared many times as a primary parasite from the nut casebearer, the leaf casebearer, and the shuckworm.

PERILAMPUS FULVICORNIS ASHM.

Perilampus fulvicornis (fig. 7) was the only secondary parasite reared in large numbers from primary parasites of the nut casebearer. The species and number of primary host larvae or pupae collected during the period 1929-31 and the parasitization effected by *P. fulvicornis* were as follows: *Apanteles epinothae*, 281, 12 percent; *Bassus acrobasis*, 550, 28 percent; *Calliephialtes grapholithae*, 72, 1.4 percent;



FIGURE 7. Adult of *Perilampus fulvicornis*.

Microbracon variabilis, 501, 0.8 percent; *Perisicrola cellularis* var. *punctaticeps*, 489, 5.3 percent; and *Orygilus maculiventris*, 32, 34 percent. *P. fulvicornis* was also reared from *Phaenotoma tibialis*, a primary parasite of the nut casebearer, and from *P. fasciata* (Prov.), a primary parasite of the slugworm.

Perilampus fulvicornis has been found overwintering in the body of larvae of the nut casebearer and the slugworm that have been parasitized by *Apanteles spinolius* and *Phaenotoma fasciata*. Second-stage nut casebearer larvae were collected in the orchard in September, and were supplied with food until they formed hibernacula in the insectary in October 1931. Early in the following April the nut casebearer larvae cut out of their hibernacula, and were again supplied with food. Late in April *A. spinolius* larvae emerged from the nut casebearer larvae. In May two adults of *P. fulvicornis* emerged from two cocoons of *A. spinolius*.

SUMMARY

Twenty-six species of primary parasites were reared from the pecan nut casebearer in Texas in 1929-31. Observations were made on the biology of these parasites and an effort was made to rear the more useful ones in large numbers.

In 1930 *Trichogramma minutum* Riley parasitized 48 percent of the first-generation eggs, 11 percent of the second-generation eggs, and 8 percent of the third-generation eggs. However, *Trichogramma* proved ineffectual in the control of the casebearer.

Five species of secondary parasites were reared in 1930-32. *Perilampus fulvicornis* (Ashm.) was the only secondary parasite that was reared in large numbers from primary parasites of the nut casebearer. *Calliephialtes grapholithae* (Cress.) and *Secodella* n. sp. act as both primary and secondary parasites.

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