in the field and laboratory; and Mr. Charles Wagner, for very excellent technical assistance.

REVIEW OF LITERATURE

The first comprehensive work on the biology of *Pseudaletia unipuncta* was that of C. V. Riley, published in his Second Missouri Report (1870). Riley added to this work in his Eighth Missouri Report (1876), and published a complete compilation of his work in the Third Report of the United States Entomological Commission (1883). In the interim years, 1870-1882, Riley published many separate articles on various phases of armyworm biology, but all of his findings as well as a good review of all that was known about the species up until that time are included in the 1883 report of the Entomological Commission. In this report Riley included sections on nomenclature, geographical distribution, capacity for injury, past history, descriptive characters, habits and natural history, generation studies, hibernation, natural enemies, control measures, and a complete bibliography.

After Riley's work, the next important armyworm contribution came in 1896 when Slingerland published on the subject in Cornell Bulletin 133. This publication gave an account of the life history of the species, described a serious outbreak, and included a brief discussion of parasites. In that same year, 1896, Flagg and Field in Rhode Island, and Warren in Pennsylvania, published on the life history of the armyworm in their respective states. Garmon, in 1908, published a detailed bulletin on the armyworm and its habits in Kentucky.

During the years 1914-1916, many writings appeared in the literature following a severe outbreak over much of the United States and Canada in 1914. The best of these treatises appear to be those of Fernald in Massachusetts (1914), Britton in Connecticut (1915), Baker and Gibson, both in Canada (1915), Davis and Satterthwait in Indiana (1916), Knight in New York (1916), and the United States Department of Agriculture Farmer's Bulletin 731 (Walton, 1916). Collectively, these publications give much information on the 1914 outbreaks in the respective areas, historical accounts, life history and seasonal cycle notes, distribution records, and lists of natural enemies, and they impress upon the reader the severity with which the armyworm attacks in outbreak years.

Flint (1920) published a brief but good account of the life history, habits, and control of the armyworm in Illinois. In 1921 Tryon published an article giving the life history and description of stages of the armyworm in Queensland.

Mickel, in 1932, published a brief account of Minnesota

armyworm outbreaks of that year. In 1938, Britton reported a Connecticut outbreak as being the worst since 1914 and gave notes on life history and parasites.

Walton and Packard reported on the armyworm in the United States Department of Agriculture Farmer's Bulletin 1850, in 1940, and a revision appeared in 1947. Both of these publications give a description of all stages, a discussion of parasites, and detailed control measures.

Of the publications listed in this review, the more important ones are those of Riley (1883), Slingerland (1896), Gibson (1915), Davis and Satterthwait (1916), Knight (1916), Flint (1920), Mickel (1932), and Walton and Packard (1947).

Breeland (1957) prepared a comprehensive bibliography of literature dealing with the armyworm, which, when used with an earlier one prepared by Riley (1883), offers a nearly complete record of literature on the species since colonial times.

To the writer's knowledge, not since the work of Davis and Satterthwait (1916) has there been any original fundamental research reported on the life history of the armyworm.

Aside from the basic references listed here, scores of articles and reports have been written in which the armyworm has been mentioned, or has been the principal subject. Most of these articles, however, are of the type that report the occurrence, outbreak damage, occasional reared parasites, or some incidental observation in governmental, state, or industrial entomological reports. There are several papers, rather detailed, which deal with parasites, predators, diseases, or other specific areas of investigation, but by far the majority of references in the literature contribute, at best, only minor bits of information. In this work, the author has endeavored to draw from as many sources of information as possible and all contributions in the literature which have come to his attention have been considered.

MATERIALS AND METHODS

A stock colony of armyworms in various stages was maintained in the insectary at all times during the course of this project. Because of the structure of the insectary, temperature, moisture, and light conditions were much the same as outside. The upper half of the insectary building was open on two sides with no artificial heating or cooling devices. For the major part of this work, data were gathered from especially designated colony groups reared in this half-enclosed insectary. The colony was started by capturing living adult armyworm moths in a cage designed for that purpose over which a light trap head was placed. Each captured gravid female moth was given a collection number, a corresponding record sheet was prepared, and

the moth was placed in a one-gallon wide-mouth jar. The top of the jar was cut out and replaced with screen wire to allow a free passage for air and a place to attach an oviposition paper. On the top of the screen was placed a cotton plug saturated with a weak sugar solution on which the moth fed. The oviposition paper was prepared by tightly folding strips of regular note paper in accordion style and taping around either end with cellophane tape. The folded paper was about six inches in length, one-fourth to one-half inch wide, and contained about six folds. It was suspended from the screen top by a small wire. Very satisfactory oviposition was obtained by this method. The

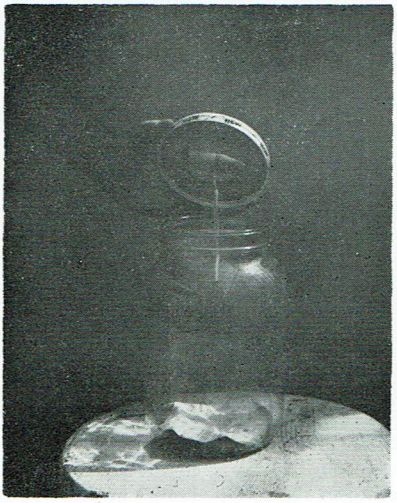

Fig. 1. Jar used for housing moths for observations on mating, longevity, and oviposition.

entire apparatus is shown in figure 1. Each day the contents of the jar were examined, the condition of the moth recorded, any eggs counted and designated by lot number, and fresh food and oviposition paper supplied. The eggs were transferred immediately to metal salve boxes of two or four-ounce size and allowed to hatch. A small amount of food, usually Johnson grass, corn, or small grain leaves, was placed with the eggs to assure sufficient moisture and immediate food supply for hatching larvae. Emerging larvae were counted and the results recorded. The larvae were kept in the salve boxes by egg lot number until they began to be crowded at which time they were transferred

to one-gallon wide-mouth jars of the type used for adult oviposition. The jars were labeled and the specimens were fed daily. The dates of the first and last pupations were recorded for each jar to determine the duration of larval development for each group. The pupae were removed daily from all groups and kept collectively by date of pupation. The first and last days of adult emergence were recorded to determine the duration of the pupal stage. The adults obtained from the insectary-reared material of the original stock were used to maintain the colony. Typically, two adult males were placed in a jar with one female and allowed to mate. The female subsequently was allowed to oviposit as has been previously described. The com-

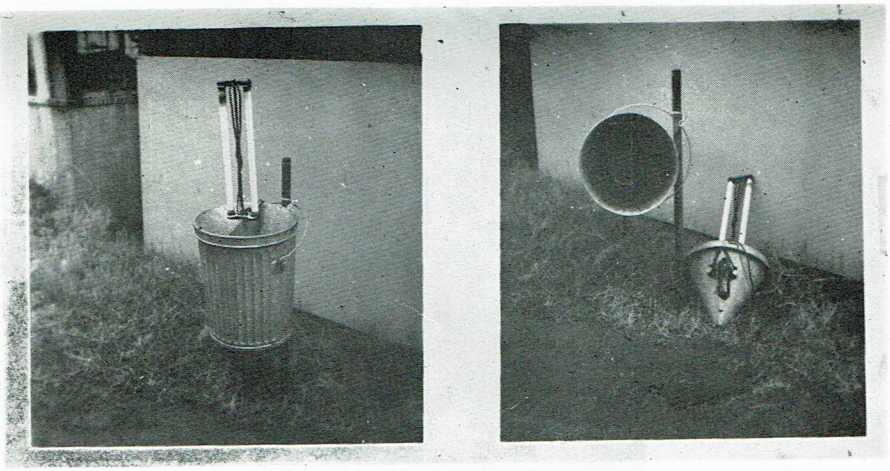

Fig. 2. Tennessee model light trap. Left, trap in operating position; right, trap dismantled.

bination of two males to one female proved to be superior to other combinations in earlier experiments. Complete records of condition, oviposition, and longevity were kept on the adults placed in the jars. This rearing procedure, with detailed records on each moth and its progeny, was begun with the first flight of moths in early spring of 1957 and continued through the fifth flight of 1957. Rearing methods were similar in 1956, but records were not as detailed and were used only for working out the number of annual broods.

In addition to the rearing jars, a larger cage, two feet by two feet by four feet, of plastic screen over a wooden frame was used to provide supplementary material for brood studies. This cage could satisfactorily house fifty moths. As many as

twenty thousand eggs were obtained in one week from this cage. The eggs gathered from this larger cage were handled in the same manner as were those from the jars.

During the course of this investigation, many field collections were made for parasite emergence studies. Specimens were collected alive in various larval stadia, given a field collection number, and brought immediately to the insectary. The specimens were subsequently isolated, one each, in two-ounce metal salve boxes and were given an identification number. A corresponding record form was prepared for each specimen. The isolated specimens were kept at room temperature, examined daily for changes, and given fresh food. When parasites emerged they were allowed to harden, were subsequently killed and pinned or otherwise preserved, and given an identification number. Pertinent data were recorded.

Frequent observations were made in the field for information to correlate with insectary data. Collections were made during each month of the study from March, 1956, through October, 1957. Material and observations from these collections were carefully handled and pertinent data were recorded.

During both seasons of this study, comprehensive light trap operations were employed for the purpose of obtaining information on flights of the armyworm moth in the state. These data were used to supplement life history studies in the field and insectary. During both seasons, eleven traps were in operation with the exception of the early part of the 1956 season, when only eight were used. Eight traps were the property of the Tennessee Agricultural Experiment Station and three were supplied by the United States Department of Agriculture. Figure 2 shows the Tennessee trap in dismantled and operating position. The lamps were 15-watt black light fluorescent tubes. The killing agent was 70 per cent isopropyl alcohol. The trapped insects were collected by the writer or were mailed to him weekly by cooperating individuals throughout the state. Figure 3 shows the locations of the traps.

Certain studies in this work called for the development of various methods which may be best explained in the text.

SYSTEMATIC HISTORY AND SYNONYMY

The armyworm moth was first described and named by A. H. Haworth in 1810 from the collection of a Mr. Francillon in London. Haworth described and named the species from a Francillon specimen without locality label as *Noctua unipuncta*. In 1829, Stephens published a description of the specimen, by mistake as *impuncta* instead of *unipuncta*, a *lapsus calami*. In 1850, Stephens corrected his mistake, placed the species in the

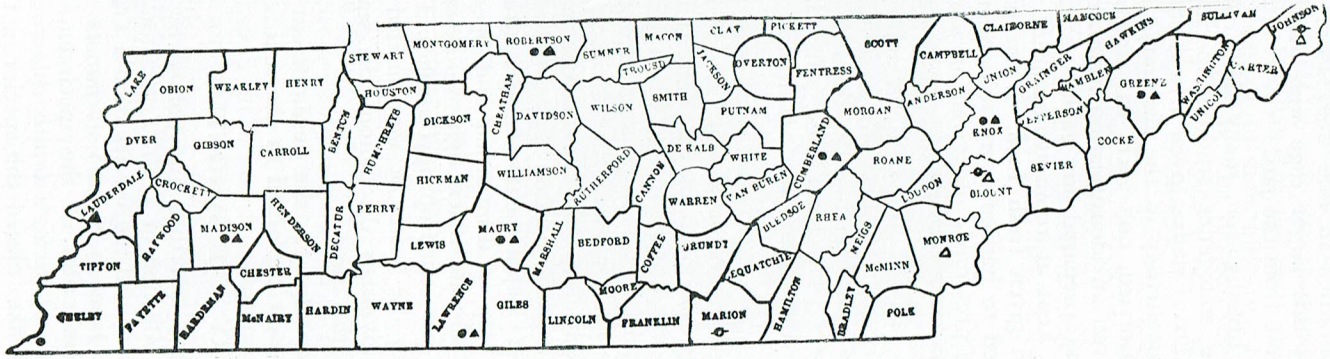

Fig. 3. Map showing locations of light traps in Tennessee by counties.

Solid Dot—University of Tennessee light trap.
Operated March 5, 1956-
November 12, 1965.

Solid Triangle—University of Tennessee light trap.
Operated March 11, 1957-
November 11, 1957.

Outline Dot—U. S. Department of Agriculture light trap.
Operated May 7, 1956-
November 12, 1956.

Outline Triangle—U. S. Department of Agriculture light trap.
Operated March 11, 1957-
November 11, 1957.

genus *Leucania,* and stated the insect to be North American. In 1852, Guenée, overlooking previous descriptions, described the species as new from numerous specimens in Parisian collections as *Leucania extranea.*

The species has been placed in several genera following the classification set forth in various systematic groupings. The two most commonly applied generic names prior to the twentieth century were *Heliophila* Huebner, 1806, and *Leucania* Ochsenheimer, 1816. The former name has been used by those who accept the "tentamen" of Huebner, the latter by those who reject it.

In 1905, Hampson included *unipuncta* in the genus *Cirphis* Walker. This name, *Cirphis unipuncta* is the more familiar one to workers of the present generation. However, McDunnough (1937) pointed out that the use of the name *Cirphis* for our North American species is incorrect, based as it is on the genitalia of the genotype, *costalis* Walker, a Tasmanian species, and recommended the reversion to *Leucania* Ochs. Franclemont (1951) confirmed McDunnoughs observations and stated that the name *Cirphis* which Hampson applied to the *unipuncta* group, is untenable because the genotype is not congeneric with any of the American species. Thus, Franclemont included the *unipuncta* group in the genus *Pseudaletia* with *Leucania unipuncta* as the type. The synonymy follows.

Pseudaletia unipuncta (Haworth)

1810. *Noctua unipuncta* Haworth. Lepidoptera Brittanica, Pars 2, p. 174. Location of Type: British Museum (Natural History).

1829. *Noctua impuncta* Stephens. Illustrations of British Entomology, Haustellata, Vol. 3, p. 80. (*lapsus calami.*)

1852. *Leucania extranea* Guenee. Histoire Naturella des Insects, Species General des Lepidopteres, Vol. 5 (Noct. 1), p. 77.
Location of Type: United States National Museum.

1951. *Pseudaletia unipuncta* Franclemont. Proc. Ent. Soc. Wash., Vol. 53, p. 65. (New combination)
Location of Lectotype: United States National Museum.
(USNM Type No. 60993)

GEOGRAPHICAL DISTRIBUTION AND HOST PLANTS

The armyworm is cosmopolitan in distribution having been reported from all of the major land masses of the world. It appears to be North American in origin and reaches its destructive peak in the United States east of the Rocky Mountains and in Canada. It is particularly abundant throughout the region from Iowa and Maine south to Texas including the Atlantic and Gulf States and all of New England. To the west of the Rockies the armyworm is not common but has been reported from Cali-

fornia (1902), New Mexico, Arizona, Utah, Oregon, Washington, and Montana; also from British Columbia and Alberta, Canada (Crumb, 1956). It appears in all of the eastern provinces of Canada, more notably in Ontario and Nova Scotia (Gibson, 1915).

Although the armyworm feeds on a great variety of plants the world over, the grasses must be considered its basic food. It particularly attacks small grains, i.e., wheat, oats, barley, rye, and rice. With equal relish it attacks pasture grasses of all types. The large-stem grasses, e.g., corn, sugar cane, millet, and sorghum are readily attacked. In addition to grasses, the species frequently feeds on alfalfa and occasionally on clover. The worms occasionally become so numerous in their breeding grounds as to devour their food supply before they have attained full growth, and search for food elsewhere. Under such stress of hunger, they consume a great variety of food plants. Forbes (1905) reports the species feeding on strawberry, bean, sugar beet, sweet potato, parsley, watermelon, cucumber, apple, pepper, honeysuckle, ragweed, and amaranth. The same author reports that in confinement armyworms have grown and completed their development when fed exclusively on poppy, beet, lettuce, cabbage, raspberry, onion, parsnips, radish, carrot, or pea. Massachusetts cranberry bogs have often been attacked by the armyworm (Franklin, 1915). Peaches and plums have been infested in Queensland (Jarvis, 1926), artichokes in California (Lange, 1941), and in Japan, Kumashira (1938) reported the armyworm attacking a rush, *Juncus effusus decipiens,* used for mat making. Almost without exception, large populations of armyworms develop in rank-growing grain crops, damage to other crops being secondary.

LIFE HISTORY AND HABITS

General Life History in Tennessee

The armyworm overwinters in Tennessee as a partially grown larva. Upon the advent of extended warm weather in early spring the overwintering larvae complete their development, pupate in the soil, and begin emerging as adults, with the peak of spring emergence occurring in mid-April. The spring flight is the beginning of the first of five broods of a given year. The moths deposit their eggs in tightly compact masses in or near rank-growing fields of young grain or other small grasses. The eggs (figure 4), numbering up to 1800 from a single moth over a period of several days, hatch in from three to fourteen days from the time they are deposited, depending upon prevailing temperatures. The newly hatched larvae begin feeding immediately on young tender blades of grass, eating the epidermis and having a skeletonizing effect. This type feeding is characteristic of the first two of the six larval instars. The remaining instars, third through sixth, straddle the outer margin of the grass

blade and cut holes from the margin to the midrib until the blade is stripped clean. The duration of larval development from eclosion to pupation averages about thirty-four days for the first brood. The first brood worms reach maturity in late May and pupate in early June. Pupation is preceded by a short prepupal period of a day or more during which time the worms do not feed. The pupal stage is spent in the soil at a depth of about an inch or less and lasts for an average of thirteen days, producing moths in mid-June which are the parents of the second brood. There are four complete broods and a partial fifth brood which enters the winter as partially grown larvae to complete the annual cycle. The length of time necessary to complete a brood varies with the season and details are given in the studies of the seasonal cycle. The first brood is the damaging one in Tennessee and any outbreaks which occur are likely to come no later than the first week of June.

THE MOTH

Description (See figure 4)

The author cannot improve upon the description of Riley (1883) which follows:

> The parent moth is variable in size, the average individual measuring about 40 mm. (an inch and a half) in wing expanse. The front wings are pointed at the tips, and are of a reddish gray or fawn color, much specked with black atoms. Anterior of the center of each wing are two rather large, indistinct spots, distinguished from the rest of the wing by an absence of black specks, and by a clearer reddish coloring. Immediately posterior to the outermost of these spots is a white point indistinctly surrounded by blackish. A series of black parallel with the outer margin; one on each vein is usually perceptible. An oblique black streak starts from this line of dots, and ascends to the apex of the wing, and, with the form of the wings, principally characterizes the species. Just inside the fringe is a series of black dots, one between each of two veins. The hind wings are translucent gray, with the terminal border and the nervures blackish (in the front wing the nervures are whitish). The sexes differ from each other but little.
>
> The under side of the wings is of an opalescent yellowish white. Along the outer margin, particularly of the hind wings, are many black specks, so nearly confluent as to form a definitely limited dusky terminal band. On the costal margin of each forewing, near the tip, is a small distinct, black dot, and at the center of each hind-wing is a similar dot. The body is concolorous with the wings, and the legs are light gray, slightly tinged with reddish, and speckled with black dots.

Drawings of both the male and female genitalia are given in figure 5. Franclemont's (1951) drawings have been checked against the genitalia of several specimens of Tennessee moths of each sex and a favorable comparison was found.

An excellent color figure of the moth appears in Holland's (1908) "Moth Book," plate 24, figure 40.

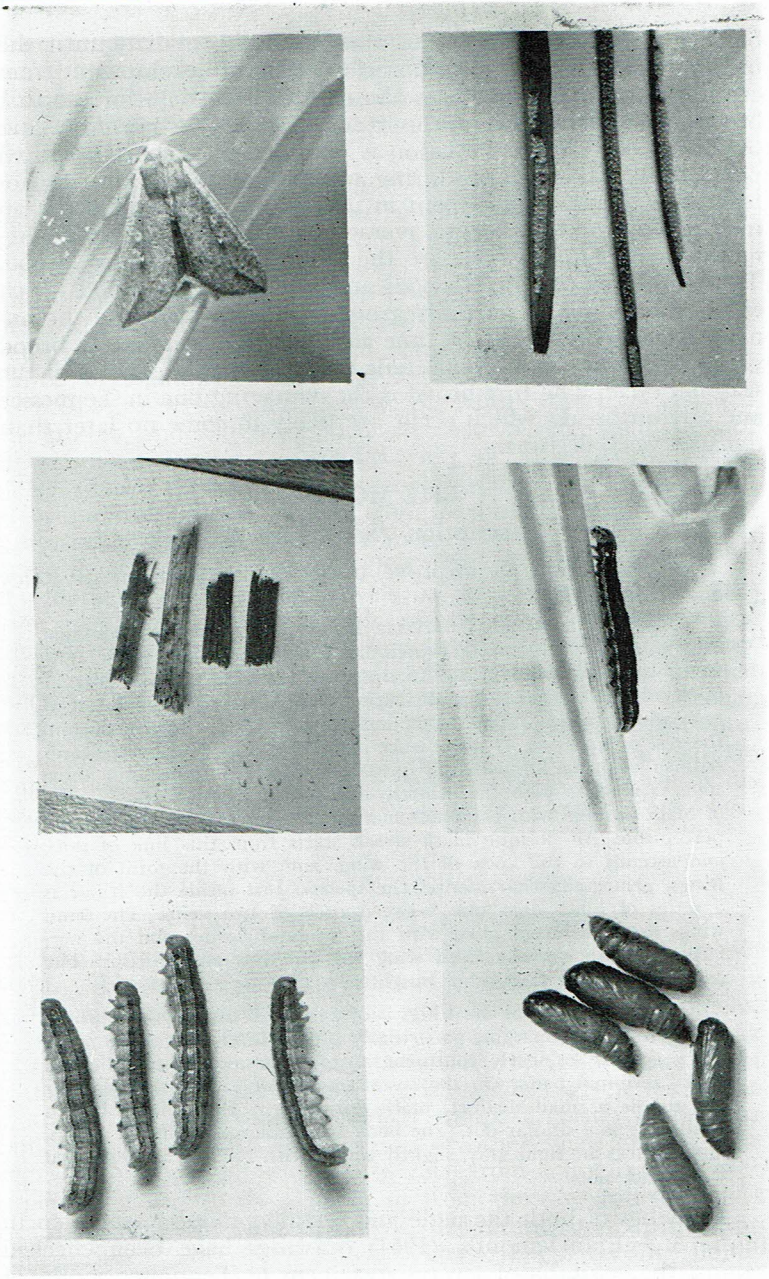

Fig. 4. Stages in the life history of *Pseudaletia unipuncta*: upper left, moth; upper right, egg masses; middle left, young larvae; middle right, mature larva in feeding position; lower left, a group of mature larvae; lower right, pupae. Natural size.

Sex Differences

Superficially, the sexes of *P. unipuncta* moths are not easily distinguishable, but reliable characters for their separation do exist. Differentiating characters, some of which are illustrated in figure 6, are as follows:

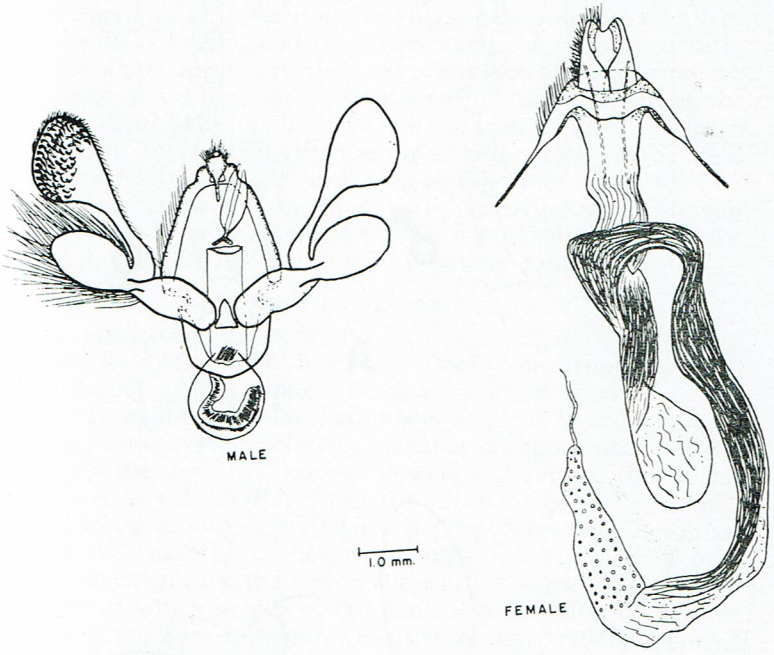

Fig. 5. Genitalia of *Pseudaletia unipuncta* (Haworth).

Male	Female
1. Tip of abdomen rather blunt.	1. Tip of abdomen more pointed.
2. Antennae hairy, especially at base (figure 6A).	2. Antennae relatively smooth (figure 6A).
3. Paired claspers prominent feature of external genitalia (figure 6B).	3. Single ovipositer prominent feature of external genitalia (figure 6B).

The genitalia may be easily seen in freshly killed specimens by rolling a round pencil or similar object from about the middle of the venter of the abdomen posteriorly, causing the external genitalia to protrude. A similar protrusion may be accomplished on living specimens by applying very slight pressure, so as not to injure the moth, with the thumb and forefinger just anterior