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This work is part of a thesis submitted by the senior author in 1980 to the Graduate School of the University of Maryland in partial fulfillment of the requirements of the M.S. degree.

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Bionomics and Taxonomy of the Euonymus Scale, Unaspis euonymi (Comstock), and Detailed Biological Information on the Scale in Maryland (Homoptera: Diaspididae)

S. A. Gill[1/], D. R. Miller[2/] and J. A. Davidson[3/]

Introduction

The euonymus scale, Unaspis euonymi (Comstock) is a serious imported pest of Euonymus species (spindle tree). In Maryland, where this ornamental often is grown, insecticide treatments commonly are required for the maintenance of healthy plants. There are no detailed descriptions of all instars of U. euonymi nor are there extensive bionomical data concerning this species in Maryland. The objective of this study is to provide a thorough understanding of the bionomics and taxonomy of this important pest with the hope that this information will be useful in the development of pest management programs.

Literature Review

ECONOMIC IMPORTANCE

Many Euonymus species that are grown commonly as ornamentals sustain considerable damage from the euonymus scale, a pest that has been of concern for many years. The economic impact of the scale is suggested by Sanders

1/ Cooperative Extension Service, Montgomery County, Gaithersburg, MD 20760
2/ Systematic Entomology Laboratory, IIBIII, Agr. Res. Serv., S&E, USDA, Beltsville, MD 20705
3/ Department of Entomology, University of Maryland, College Park, MD 20742

Variations have been reported in the time required for newly hatched crawlers to reach the adult stage. In Virginia, 6 weeks were required for the first generation to mature and 4 or 5 weeks for the second (Underhill, 1943). In Massachusetts, Warner (1949) reported that the first generation required 63 days to mature in 1948 and 49 days in 1949, and Cantelo (1953) noted that about 46 days were needed for each generation. Under greenhouse conditions (75-85° F) a generation required 21 to 30 days to mature (Dabbour, 1967) and in temperature-controlled cabinets the generation length ranged from 68 days (60° F) to 44 days (70 F)(Cantelo, 1953).

Egg laying in Oklahoma (Dabbour, 1967) began in early April, peaked in late April and continued until late September. In Massachusetts, Warner (1949) reported that first-generation eggs were laid in mid-June to mid-July, and second-generation eggs in late August to late September; Cantelo (1953) found second-generation eggs from July to October. In Hungary, Vinis (1977) found that egg laying began in early April.

The number of eggs laid by each female was reported by Chapman et al. (1931) in Virginia as 60 to 157(98), by Dabbour (1967) in Oklahoma as 30 to 50, by Cantelo (1953) in Massachusetts as a maximum of 43, by Warner (1949) in Massachusetts as an average of 50 and a maximum of 80, and by Vinis (1977) in Hungary as 30 to 50. Cantelo (1953) found 48 eggs in one dissected female, and Underhill (1943) found 63 to 143 embryos in dissected females.

Eggs required 2 or 3 days to hatch after oviposition in Oklahoma (Dabbour, 1967) and 24 to 48 hours in Hungary (Vinis, 1977).

Crawler emergence periods are reported to be closely correlated with egg-laying times since eclosion occurs soon after eggs are produced. Crawler emergence periods were: May through June for the first generation and beginning in mid-July for the second generation in Ohio (Kosztarab, 1963; Neiswander, 1966); mid-June to early July for the first generation and mid-August to early October for the second generation in Connecticut (Schread, 1970); late May for the first generation and mid-July for the second generation in Virginia (Johnson and Lyon, 1976); late April or early May for the first generation and mid-July to late September for the second generation in Virginia (Underhill, 1943); crawlers appeared in late May for the first generation, mid-June for the second generation and early October for the third generation in New Jersey (Weiss, 1953); crawlers appeared in mid-May for the first generation, late June for the second generation, and August for the third generation in the Central Atlantic States (Weigel and Baumhofer, 1948); crawlers emerged in March for the first generation, June for the second generation, and August for the third generation in Alabama (Williams et al, 1977). Sanders (1909) observed that egg hatch of the first generation varied with latitude and from year to year and extended from early May to mid-June. Murakami (1970) reported that in Japan eggs hatched at the end of May in the first generation and the end of July in the second.

Crawlers moved about on the host for a few hours to slightly more than a day before settling (Cantelo, 1953; Dabbour, 1967; Warner, 1949). Duration of the first instar was reported as 13 to 18 days in Kansas (Dabbour, 1967) and

The mymarid wasps Alaptus excisus Westwood and Dicopus citri Mercet are reported as associated with this scale (Balachowsky, 1954). We question these records because mymarids have never been reared specifically from scale insects. It is possible that scale infested host material used to rear parasites was contaminated with eggs of other insects that contained mymarid parasites.

TAXONOMY

Comstock (1881) described the euonymus scale as Chionaspis euonymi collected on Euonymus latifolia in Norfolk, Virginia. MacGillivray (1921) described Unaspis as a monotypic genus including only U. acuminata (Green). Ferris (1937) placed euonymi in Unaspis, gave a revised description of the genus and included the first detailed, illustrated description of U. euonymi.

Materials and Methods

Life history information was gathered from October 1977 to October 1979. An open, sunny location adjacent to the University of Maryland Apiary in College Park, Maryland was selected as the primary research site. An additional location in Silver Spring was used to confirm synchronization of the life cycle. The primary site included 15 heavily infested plants of Euonymus japonica Thunb. (130 to 240 centimeters high) planted in a straight hedge. Three plants of E. kiautschovica (180 to 320 centimeters high) were clustered at one end of the hedge and a row of eight plants of E. kiautschovica (130 to 220 centimeters high) was located at the other end.

Throughout the year, weekly samples were taken at the primary site and periodic samples were taken at the Silver Spring site. Collections were made from the apical 12 centimeters of the branches to avoid areas encrusted with old scale covers. Life cycle charts were based solely on material collected from the apiary. Sample size varied from 50 to 200 specimens including eggs and were mounted in Hoyer's mounting medium using the formulation of Krantz (1978). The sex (except first instars) and instar of each mounted specimen were determined using a Wild M5 microscope with 100x to 1,000x magnification. Egg counts were taken differently in 1978 and 1979. The eggs from the developmental period shown in the 1978 life history chart were counted when they were first found in the bodies of the adult females. The eggs from the period shown in the 1979 chart were counted only after they were laid. Counts were terminated in early October in 1979 because the shrubs in the study area were severely pruned without our prior knowledge. We believe that the long interval between the apparent occurrence of third-instar males long after second-instar males, and the occurrence of adult males before fourth-instar males in chart 1 reflect sampling errors.

To establish male to female ratios, 10 samples were taken at random from 20 centimeters of the current year's growth of E. japonica plants. Fifty

BIOLOGY

The following sequence of events can be visualized from Charts 1 and 2 which summarize the euonymus scale life cycles observed in Maryland in 1978 and 1979.

Unaspis euonymi had three female instars and five male instars. It was bivoltine and occurred on the bark and leaves of Euonymus japonica. The overwintering stage consisted of mated, adult females. Egg production began in early May and ended in late May or early June. Crawlers were present in early May to early July. Adult males appeared from mid- to late June and adult females in mid-June. Egg laying in the second generation began in late June; crawlers appeared in mid-July. Adult males appeared in early to mid-September and adult females appeared in late August to early September. Mated, adult females overwintered and produced eggs the following spring.

Oviposition occurred for 22 and 59 days in the first and second generations respectively in 1979. Thirty-six to 67(51.6) eggs were laid by 30 unparasitized females. Eclosion times for the eggs ranged from 2 hours to nearly 2 days.

First-instar crawlers were present for 61 days in the first generation in 1978 and 41 days in 1979; second-generation crawlers were present for 102 days in 1978. Observations on crawlers indicated that mobility may last up to 48 hours after hatching. We were unable to distinguish between the sexes of first instars in the field or laboratory.

Second-instar males in the first generation were present for 31 days in 1978 and 27 days in 1979; in the second generation they were present for 36 days in 1978.

Second-instar females in the first generation were present for 61 days in 1978 and 34 days in 1979; in the second generation they occurred for 77 days in 1978.

Third-instar (prepupal) males in the first generation were present for 26 days in 1978 and 23 days in 1979; in the second generation they occurred for 58 days in 1978.

Fourth-instar (pupal) males in the first generation were present for 13 days in 1978 and 18 days in 1979; in the second generation they occurred for 25 days in 1978.

Third-instar (adult) females in the first generation were present for 85 days and in the second generation for 285 days (average of the data from 1978 and 1979).

Fifth-instar (adult) males in the first generation were present for about 18 days in 1978 and 1979; in the second generation they occurred for 47 days in 1978.

Synonymy

A complete synonymy of this species was given by Gill (1980) and included 216 literature citations. Although many of the publications cited are short discussions dealing with life history or control, taxonomic papers also are included.

For the purposes of this publication we are including a critical synonymy.

Chionaspis euonymi Comstock, 1881: 313.
Chionaspis evonymi Comstock; Targioni-Tozzetti, 1884: 396.
Chionaspis nemausensis Signoret, 1886: 9.
Unaspis euonymi (Comstock); Ferris, 1937: 130.
Unaspis nakayamai Takahashi and Kanda, 1939: 185.

Type material

The USNMNH collection contains 109 syntypes (79 adult females and 30 adult males) mounted on 19 slides. From these slides we selected as lectotype one adult female on one slide. The label on the right side of the slide, written by Comstock's assistant, Pergande, stated "No. 125. "Chionasp]is/on/ Euonymus/latifolius/Norfolk, Va." and on the left "remounted III-1980/Lectotype designated by/Gill, Miller and Davidson". The number 125 was assigned to this species when it was sent to Comstock for identification. Records kept by Pergande pertaining to No. 125 stated "July 8, '79./Rec. to day from Mr. Henry P. Worcester, P.O. Box 364, Norfolk, Va....". Based on this information, collection data of the type series of Chionaspis euonymi Comstock should be: Norfolk, Va., VII-8-1879, on Euonymus latifolia, collected by H. P. Worcester. The original description included all of these data except the date.

Hosts

We have seen adult females of the euonymus scale that were collected on the hosts Acer, Althaea, "Bay", Buxus, Camellia, Celastrus, Citrus, Daphne, Euonymus, Ficus, Fraxinus, Ilex, "Japanese yew", Ligustrum, Magnolia, Oleaceae, Pachysandra, Philadelphus, Primula, Symphoricarpos, Tripterygium and "yellow wood". Euonymus is the most commonly recorded host and we have seen material from the following species: alata (Thunb.) Sieb. americana L., atropurpurea Jacq., Bungeana Maxim., Fortunei (Turcz.) Hand.-Mazz., Hamiltoniana Wallich, japonica Thunb., Kiautschovica Loes., latifolia (L.) Mill., obovata Nutt. and verrucosa Scop. The scale has been reported to be found on about 30 of the 170 species of Euonymus. Borchsenius (1966) also recorded it on Hibiscus, Jasminum, Lonicera, Olea, Paxistima, Prunus and Syringa. Dekle (1977) also recorded it on Eugenia and Underhill (1943) recorded it on Solanum.

Body setae - Dorsally: Head with four to six(5.1); prothorax with one or two(1.2); mesothorax with zero or one(0.8); metathorax with zero or one(0.9); segments I through VII each with two; segment VIII with three; segment IX with one. Ventrally: Head with two or three(2.4); prothorax, mesothorax, metathorax and segments I and II without; segment III with zero or one(0.8); segment IV with one or two(1.8); segments V through VII each with two; segment VIII with one to three(1.6); segment IX without.

Discussion - The description is based on 10 specimens. Unaspis euonymi appears to differ from third-instar males of other species by having two ventrolateral protrusions on segment IX. These were not observed on Chionaspis nyssae, C. americana or C. kosztarabi. No third-instar males are known for other species of Unaspis.

Fourth-Instar

Males (Pupae)

(Fig. 8)

General appearance - Yellow orange. Elongate elliptical as mounted. Antennae weakly segmented, 316 to 397(352)u long, with one sensillum containing two pegs near apex of antenna. Eyespots obvious. Anal opening located near base of penial sheath. Legs weakly segmented. Wing buds 254 to 291(272)u long. Penial sheath 118 to 136(126)u long. Body of mounted specimens 713 to 862(801)u long, mesothorax 192 to 248(222)u wide.

Body setae - Dorsally: Head with four to eight(5.1); prothorax with zero to two(1.2); mesothorax with zero or one(0.8); metathorax with zero or one(0.9); segments I through VII each with two; segment VIII with two or three(2.2); segment IX with one. Ventrally: Head with one or two(1.6); prothorax, mesothorax, metathorax and segments I and II without; segment III with zero or one(0.5); segment IV with one or two(1.5); segment V and VI each with two; segment VII with one; segment VIII with zero or one(0.5); segment IX with zero or one(0.5).

Discussion - The description is based on nine specimens. No differences were found among the following: Unaspis euonymi, U. citri, U. yanonensis, Chionaspis americana, C. kosztarabi and C. nyssae.

Fifth-Instar

Males (Adult)

(Fig. 9)

General appearance - Yellow orange. Elliptical body. Antennae 10-segmented, filiform, 366 to 512(442)u long; scape widest, with well developed basal ridge and one seta; segments II and III each with sensillum,

apical segment with seven to 10(9.3) simple setae, two hairlike setae, one apical sensory seta, and one cryptic apical sensillum. Legs with setae on inner margin of tarsi divided near apex; prothoracic tibia with stout seta at proximal end; prothoracic legs 220 to 290(256)u long, mesothoracic legs 247 to 307(267)u long, metathoracic legs 271 to 323(292)u long. Front wings 549 to 702(616)u long; halters with apical seta recurved at tip. Body of mounted specimens 659 to 866(769)u long, 159 to 232(203)u wide at mesothorax.

Setae - Head: one pair on midcranial ridge near anterior apex of head, one pair on anterior to middle portion of dorsal arm of midcranial ridge and two pairs at base of ridge. One on postoccipital ridge near juncture of anterior and posterior arms. Three or four interoculars. Two on gena. Thorax: Prothorax with two on dorsum. Mesothorax with one on scutellum and one on tegular bulge. Metathorax with one posterior on postnotal apophysis and haltere. Abdomen: Normally with dorsosubmarginal on segments I through VII, one marginal on segments I and II, two marginal on segments III through VII, two or three marginal on segment VIII, one ventrosubmarginal on segments III or IV through VII, one marginal on segment VIII.

Head - Midcranial, postoccipital and postocular ridges well developed. Preocular ridge produced dorsally beyond articulatory process of basal ridge of scape. Postocular ridge fenestrated dorsally. Ocular sclerites lightly sclerotized around eyes; polygonal pattern laterad of dorsal eye. Ocelluslike spot on each gena. Mouth opening without sclerotization; ventral plates absent; tentorial pits normally not visible.

Thorax - Prothorax: Pronotal sclerites occasionally visible; pronotal ridge absent; pleural ridge and pleural sclerite well developed; prosternum with conspicuous median ridge, lateral ridges normally lightly sclerotized. Mesothorax: Prescutum with nearly straight prescutal ridge, prescutal suture inconspicuous, median groove present or absent. Scutum with polygonal reticulation restricted to lateral areas, prealare separated by distinct suture, with heavily sclerotized, crescent-shaped triangular plate. Scutellum in form of transversely elongate rectangle, with small foramen. Membranous triangular area behind scutellum with weak, longitudinal striation. Basisternum well developed, with weak median ridge, furca arms long, extending to near marginal ridge. Metathorax: Suspensorial sclerites small; metapostnotal sclerites represented by weak area of sclerotization or absent; pleural ridge and coxal ridge well developed; epimeron not obvious; episternum conspicuous; marginal ridge of metasternum poorly developed; metasternum not sclerotized.

Abdomen - Segments I through VII without sclerotization, segment VIII with small tergite. Genital segment bulbous basally, 232 to 287(267) u long, anus inconspicuous.

Discussion - The description is based on 10 specimens. The only detailed key of armored-scale adult males is by Ghauri (1962). The adult male of *Unaspis euonymi* keys with some difficulty to *Chionaspis* possessing most of the key characters listed by Ghauri. In comparison with *Chionaspis nyssae*, *U. euonymi* differs as follows: Scape with one seta, apical antennal segment

with about nine simple setae, two hairlike setae, one apical sensory seta and one cryptic apical sensillum, gena with one setae, tegular bulge with two seta, prothoracic tibia with stout seta at proximal end, polygonal retriculation restricted to lateral areas of scutum, genital segment about 267u long. Chionaspis nyssae has scape without setae, apical antennal segment with about five simple setae, no hairlike setae, one apical sensory seta and one conspicuous, subapical sensillum, gena with one seta, tegular bulge with two setae, prothoracic tibia without stout seta, polygonal reticulation on most of scutum and prescutum, genital segment about 208u long. In comparison with U. euonymi, Chionaspis salicis (L.) has scape without setae, an apical antennal segment with five or six simple setae, no hairlike setae, one apical sensory seta and a cryptic sensillum, gena with one seta, tegular bulge with one seta, prothoracic tibia without stout seta, polygonal reticulation on most of scutum and prescutum, genital segment about 333u long.

Discussion

ECONOMIC IMPORTANCE

The resistance of Euonymus kiautschovica to infestation by the euonymus scale observed in this study agrees with findings in recent literature and indicates the potential value of resistant varieties of Euonymus in preventing damage by this pest. E. alata Cv 'Compacta', E. sachalinensis (Friedr. Schmidt) Maxim. and E. sanguinea Loes. ex Diels were reported to be growing free of scale infestation at the Arnold Arboretum despite the presence of other, nearby, infested Euonymus (Warner, 1949). These apparently resistant varieties are candidates for future research as useful elements of urban integrated pest management (IPM) programs.

Biological control of scale infestations with parasites and predators is another potential element of an IPM program. After much research, several scale insect pests of fruit crops are now controlled by parasites and/or predators. To our knowledge, no serious attempt has been made to use similar agents, through importation and/or augmentation, to control scale pests of ornamentals in the United States. The euonymus scale appears to be a prime candidate as a target pest for biological control. The diversity of natural enemies of this scale in the United States seems to be unusually small. In addition, these predators and parasites are generalists on a wide variety of scale hosts. Because effective biological control agents were found and imported with other introduced scale pests, such as California red scale, we believe that comparable results could be expected by introducing new natural enemies of the euonymus scale.

BIOLOGY

Some researchers have reported four instars for the female euonymus scale. In this study, we observed that in all four generations, females had only three instars. This is consistent with the preponderance of literature on diaspidid biology, and we believe this is true for all populations of Unaspis euonymi.

The number of generations reported in the literature varied from two to five but several of these generation times were not correlated with north-south temperature gradients. Based on this study, and on an assessment of the literature, we believe that three generations can occur in the warm southern areas and two generations can occur in northern areas. It is unlikely that four or five generations a year occur in Oklahoma, or that three generations a year occur in Connecticut, New York and New Jersey.

The times given for the appearance of crawlers in the spring varied by seven days between 1978 and 1979. Based on observations of other aspidiotine and diaspidine armored-scale species studied at the University of Maryland we anticipate that this variance might reach as much as 2 weeks.

TAXONOMY

Although sexual differences in setal pattern and companiform sensilla have been found in a few diaspidine species where first instars were examined in detail, we were unable to find morphological differences in the sexes of the first instars of Unaspis euonymi.

An attempt was made to distinguish each instar of the euonymus scale from those of other species of Unaspis. Diagnostic characteristics among Unaspis species used to separate first instars and second-instar females were viewed as relatively minor; characteristics used to separate second-instar males and adult females were considered relatively major. Differences could not be discerned among Unaspis species in the fourth-instar males. Third-instar males and adult males of species of Unaspis other than U. euonymi were not available for comparison.

Conclusion and Summary

Many species of Euonymus are grown as ornamental shrubs throughout most of the United States. The euonymus scale, Unaspis euonymi, is a serious pest of the Japanese spindle tree, Euonymus japonica. Occasionally this pest infests other hosts such as Celastrus and Pachysandra. Although one parasite (Aspidiotiphagus citrinus) and one predator (Hemisarcoptes malus) were periodically abundant on infested E. japonica in the study plot, they were unable to prevent plant destruction by this scale insect.

Euonymus kiautschovica, planted near the study plants of E. japonica, failed to develop high levels of scale population and never showed damage symptoms. This is consistent with reports in the literature on plant resistance to this pest.

Unaspis euonymi is a bivoltine species in central Maryland that overwinters as mated, adult females. First instars (crawlers) of the first generation were present from early May to early July and those of the second generation from mid-July to mid-October. Five instars were found in the male and three in the female. Sexual dimorphism was not detected in crawlers of

U. euonymi but was found in all other instars. Diagnostic characteristics of each instar except the fourth-instar males that distinguish U. euonymi from congeneric and/or intergeneric species are given. These characteristics include the number and/or placement of the following structures: antennal segments, setae, ducts, spiracular pores, gland spines and abdominal protrusions.

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Chart 1. Life history of Unaspis euonymi on Euonymus japonica in Maryland in 1978. Solid bars indicate first generation; broken bars indicate second generation.

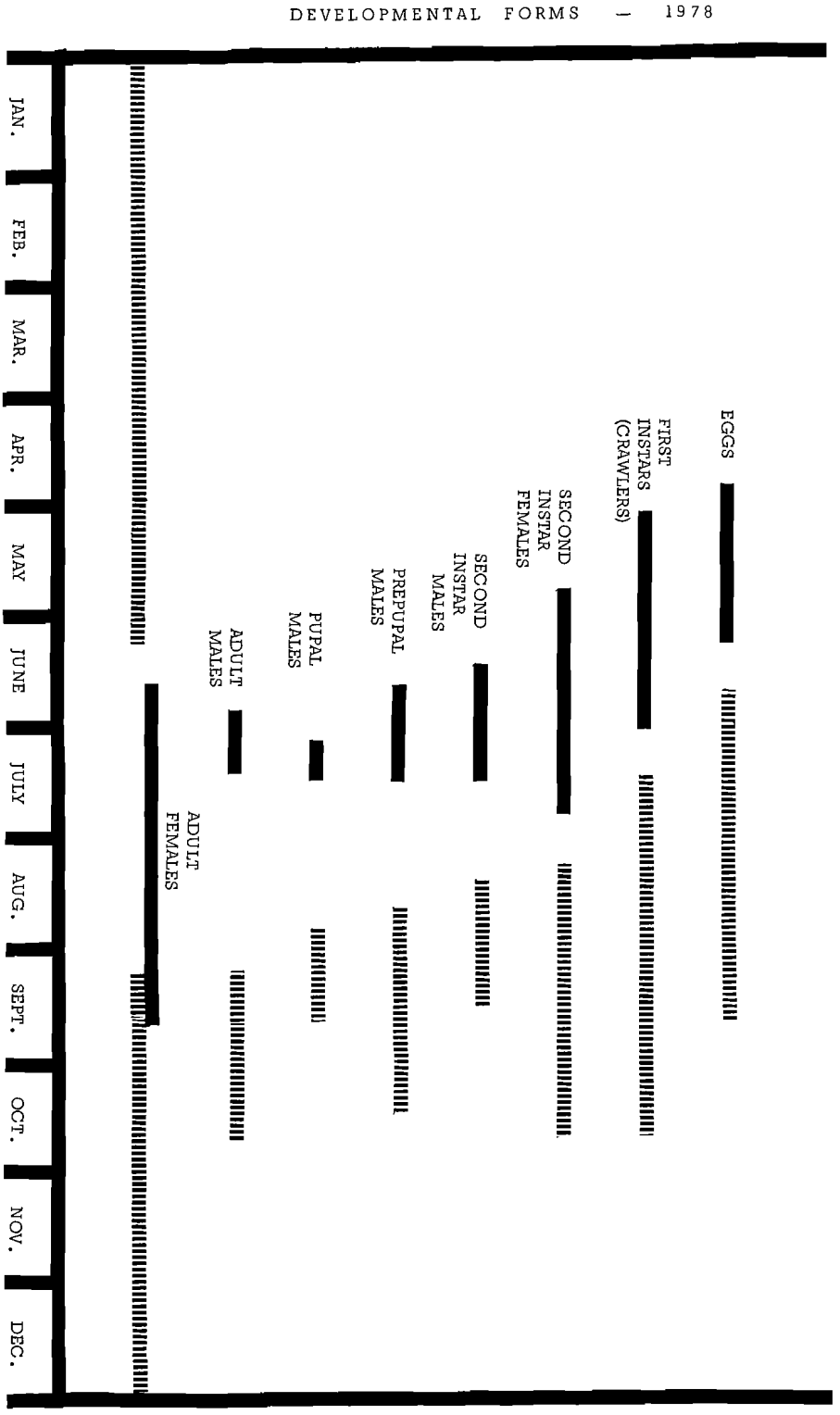

Chart 2. Life history of Unaspis euonymi on Euonymus japonica in Maryland in 1979. Solid bars indicate first generation; broken bars indicate second generation.

DEVELOPMENTAL FORMS——1979

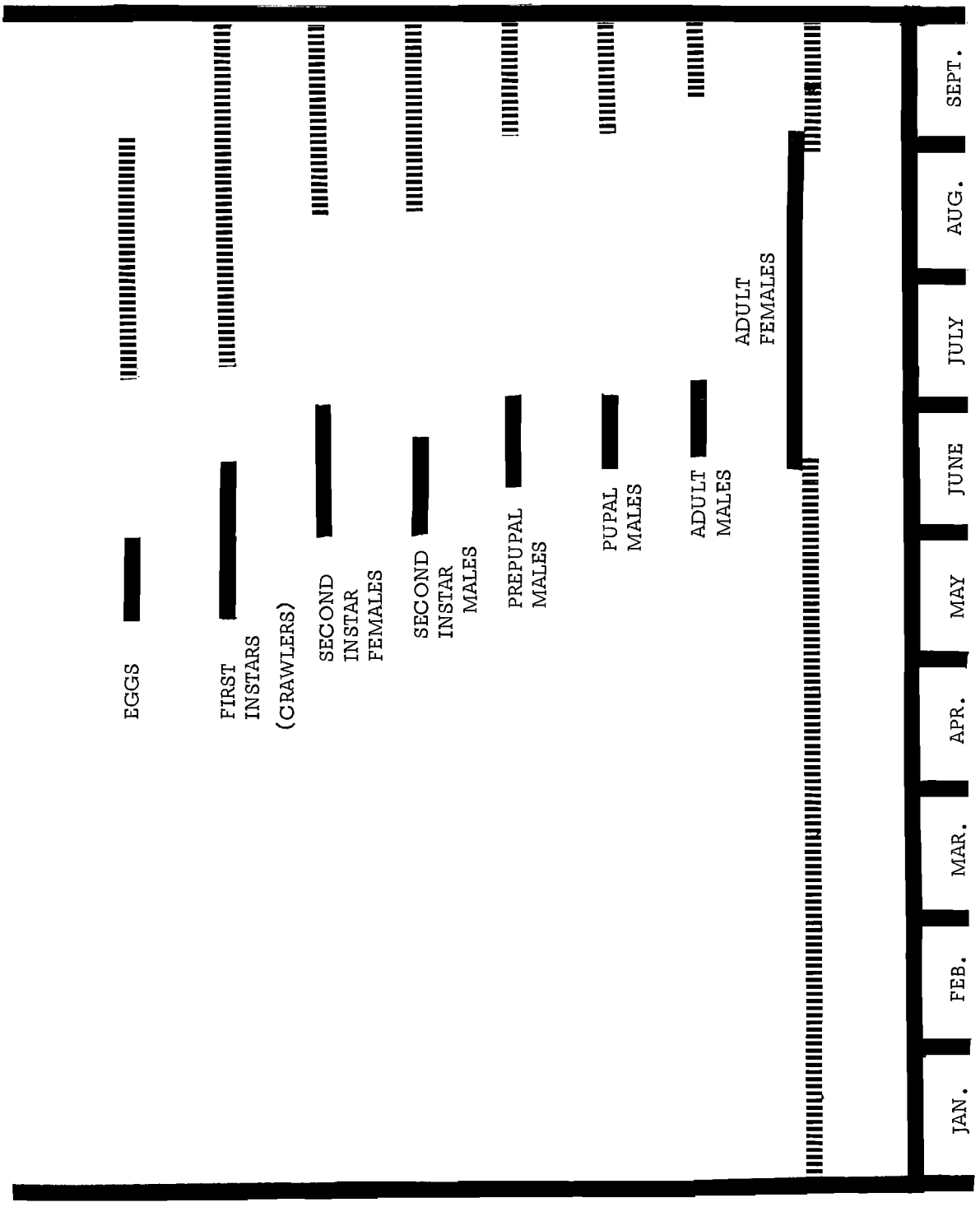

Figure 1. First-instar males and females of Unaspis euonymi (Comstock).

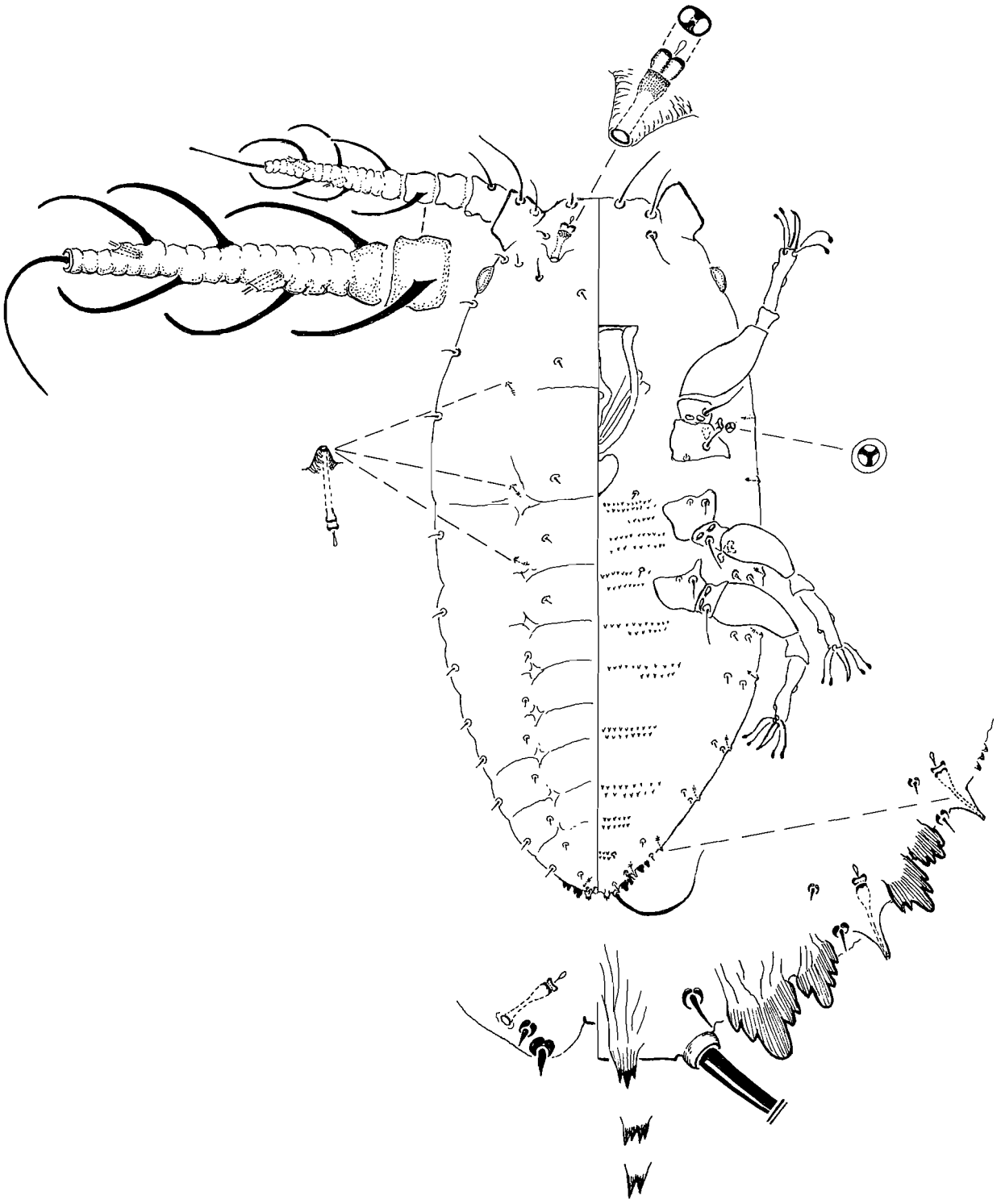

Figure 2. Second-instar females of Unaspis euonymi (Comstock).

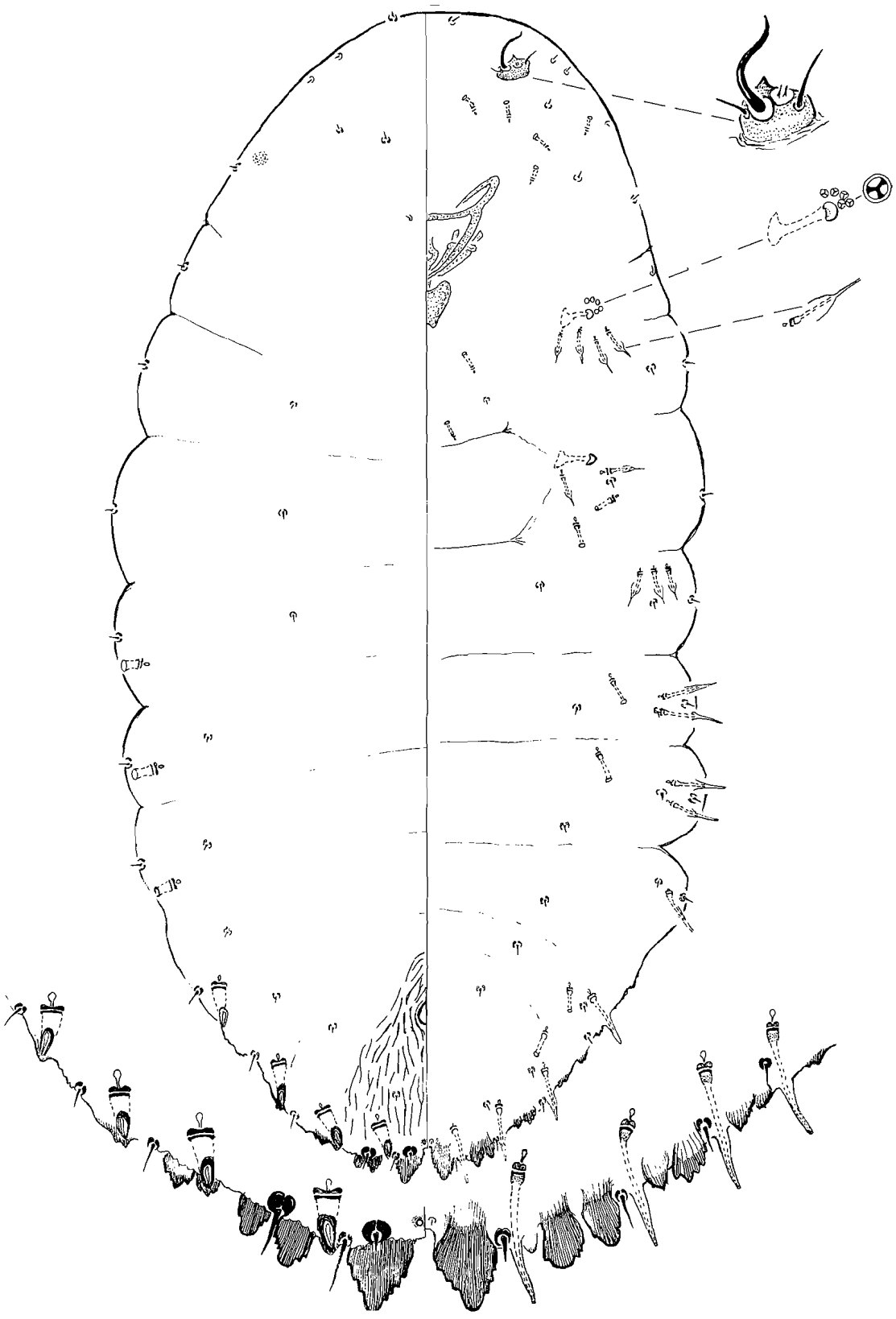

Figure 3. Second-instar males of Unaspis euonymi (Comstock). A. Gland spine of Unaspis citri (Comstock). B. Gland spine of Unaspis yanonensis (Kuwana).

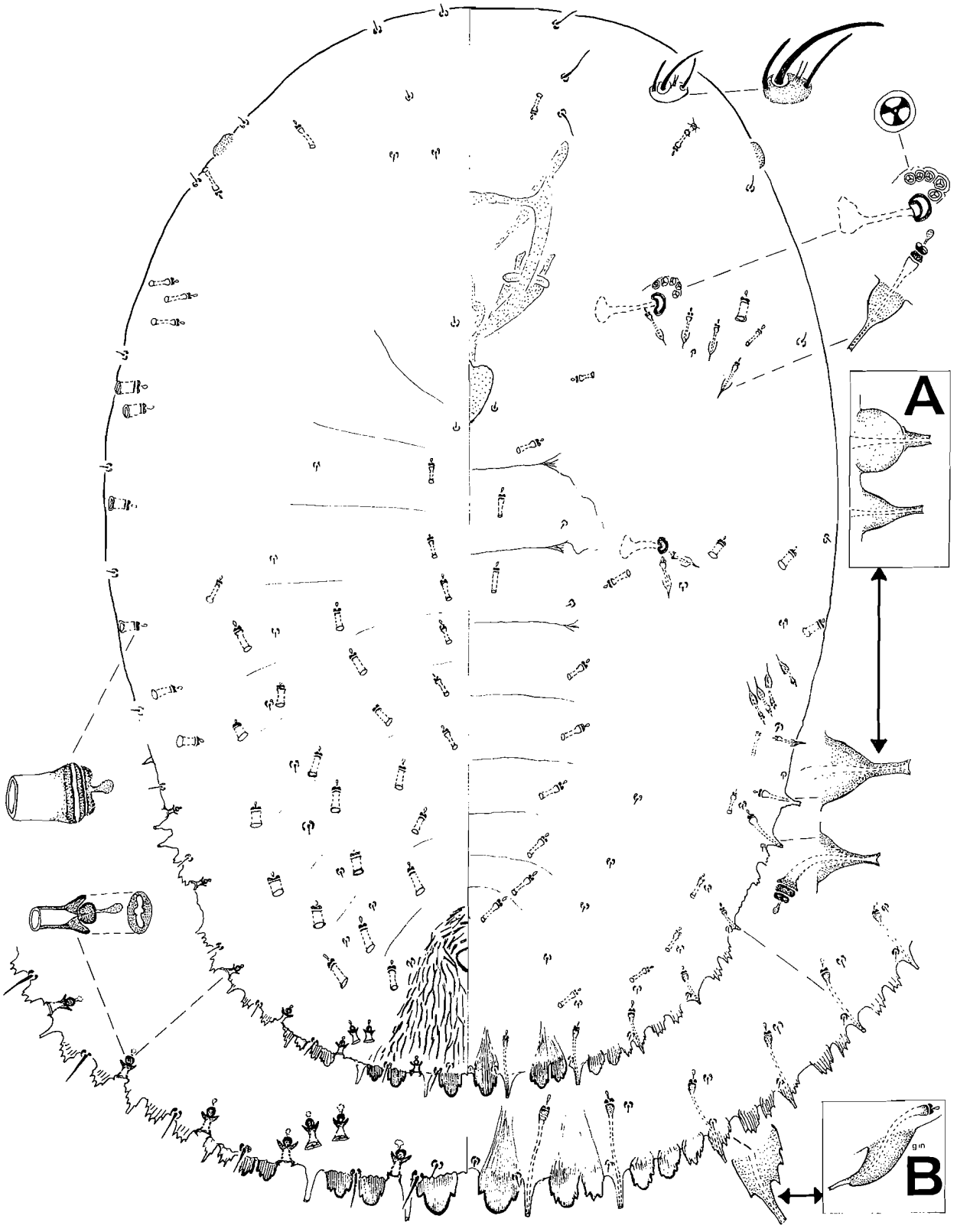

Figure 4. Second-instar male lobe variations of Unaspis euonymi (Comstock).

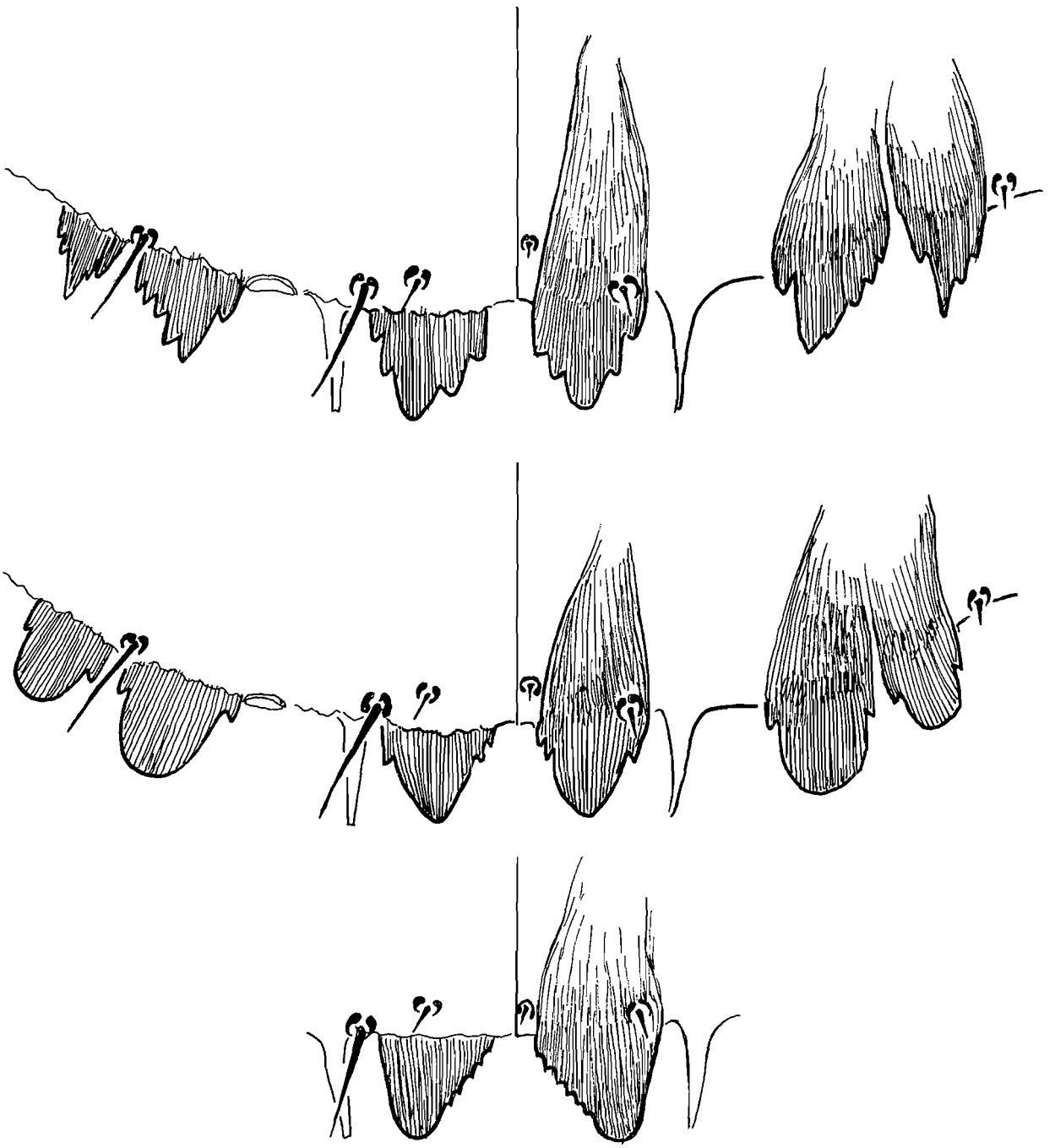

Figure 5. Third-instar females (adults) of Unaspis euonymi (Comstock).

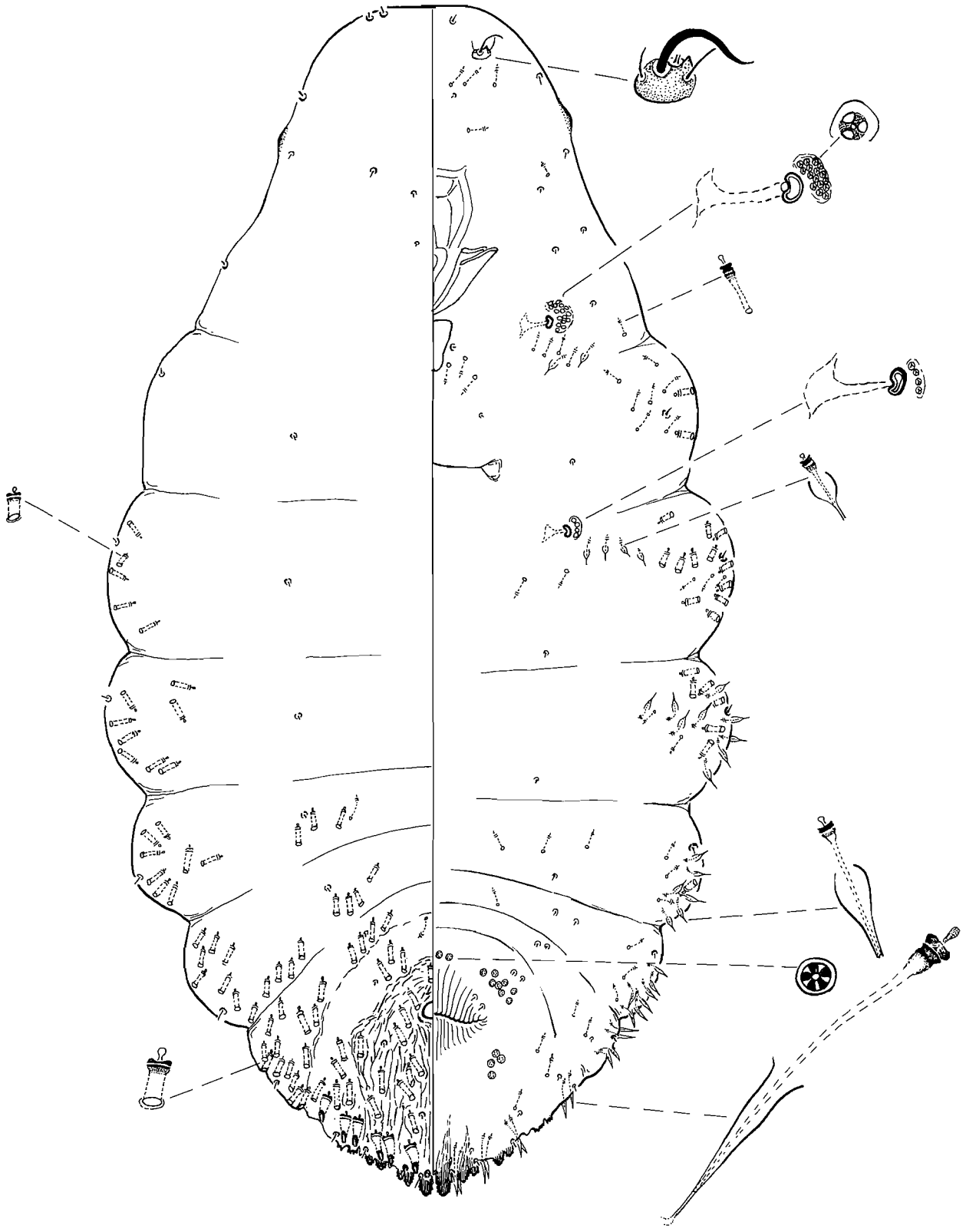

Figure 6. Third-instar female pygidial fringe of Unaspis euonymi (Comstock).

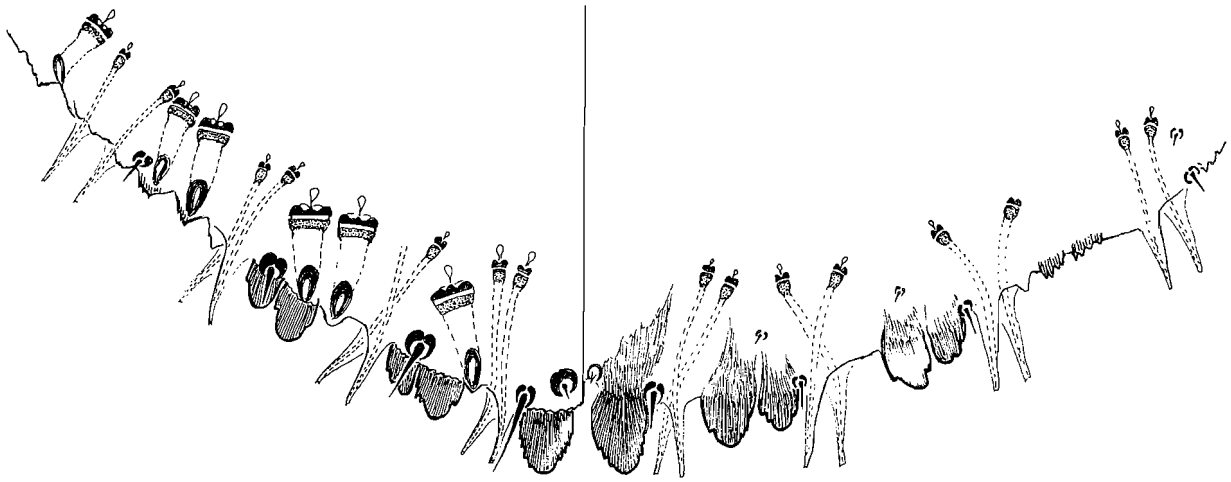

Figure 7. Third-instar males (prepupae) of Unaspis euonymi (Comstock).

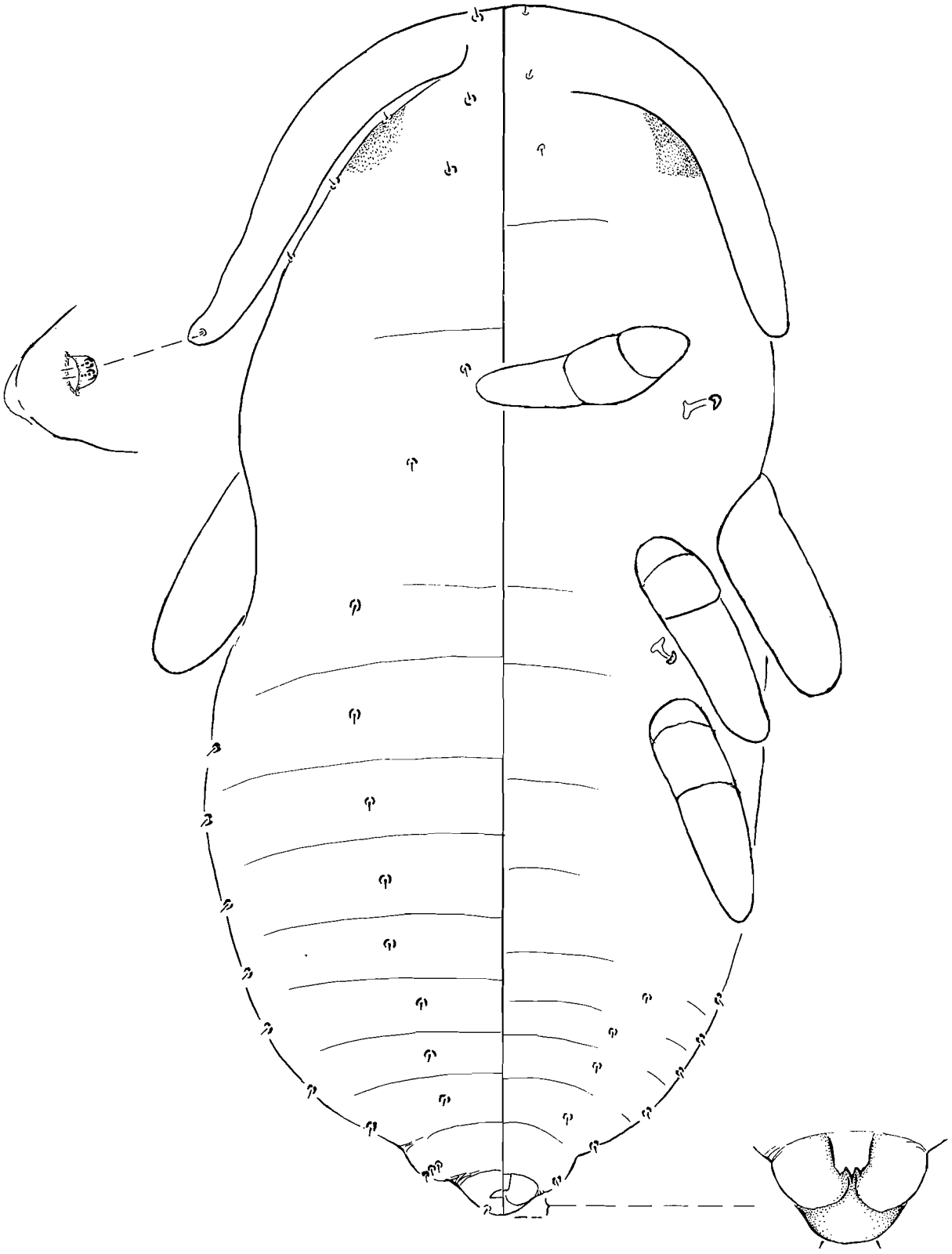

Figure 8. Fourth-instar males (pupae) of Unaspis euonymi (Comstock).

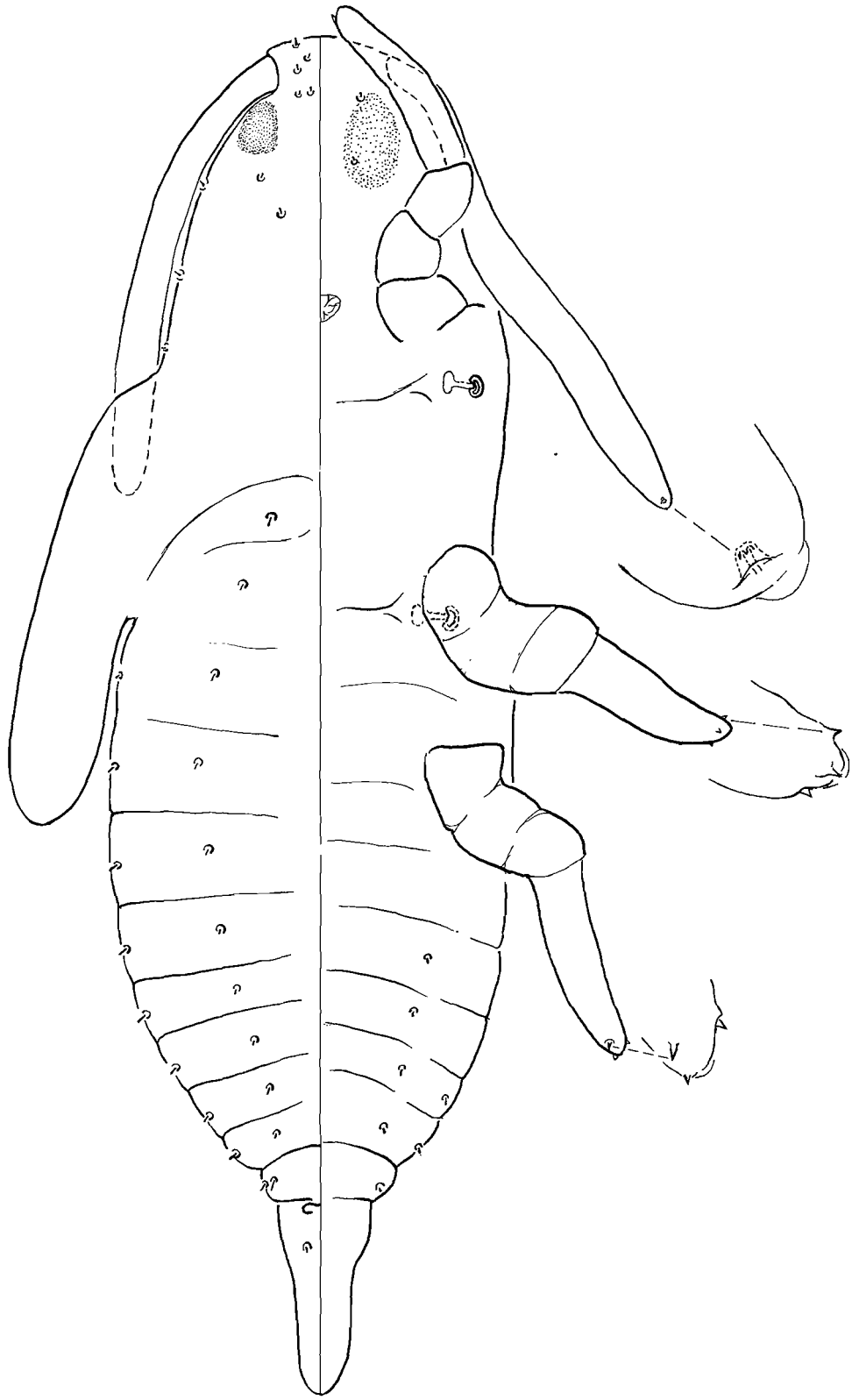
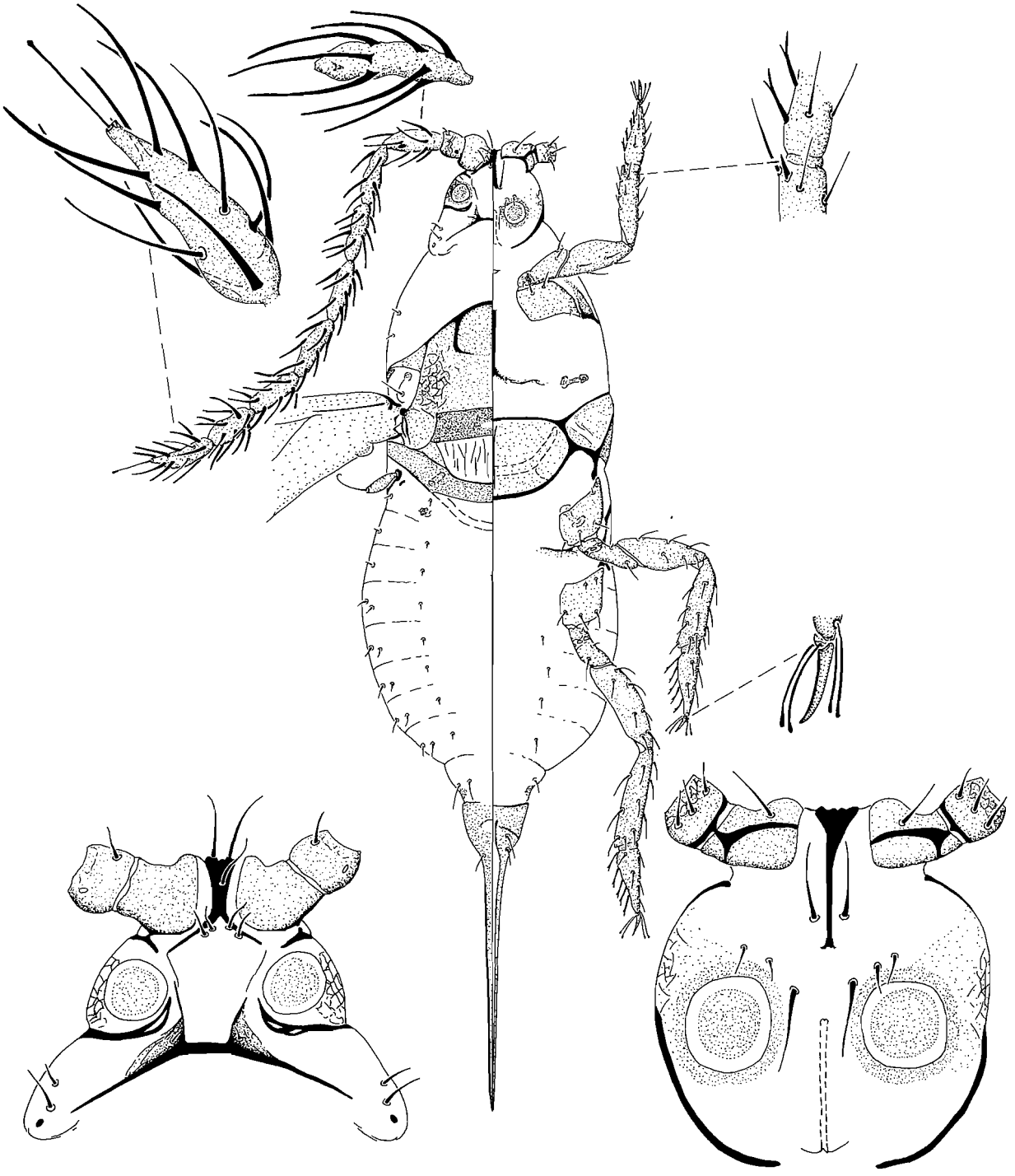
Figure 9. Fifth-instar males (adults) of Unaspis euonymi (Comstock).