MORPHOLOGICAL AND BIOLOGICAL STUDIES ON TWO SPECIES OF *CHIONASPIS* (HOMOPTERA: COCCOIDEA: DIASPIDIDAE)

by

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LIST OF ABBREVIATIONS

The terminology and abbreviations for male morphology were adopted from Ghauri (1962).

aed - aedeagus

adgt - anterior tarsal digitule

ads - abdominal dorsal setae

an - anus

aps - abdominal pleural setae

audgt - anterior ungual digitule

avs - abdominal ventral setae

ax_1 - first axillary

ax_2 - second axillary

ax_3 - third axillary

bra - basal rod of aedeagus

brps - basal ridge of penial sheath

cam. s. - campaniform sensillum

CDA - California Department of Agriculture, Sacramento (R. J. Gill)

cx - coxa

cxp_2 - metothoracic coxal process

dhs - dorsal head setae

dse - dorsal simple eye

eps_2 - mesoepisternum

f - mesofurca

fig. - figure

FDA - Florida Department of Agriculture, Gainsville (W. G. Dekle)

fm - femur

$fset_1$ - fleshy seta non-bifurcate

$fset_2$ - fleshy seta bifurcate

g - gena

gs - genal setae

gts - setae on genital segment

h - haltere

H - collected and mounted in Hoyer's medium by P. A. Willoughby

hp - humeral plate

le - spot-like genal ocellus or "larval eye"

lmcr - dorsal lateral branches of midcranial ridge

m - median vein

mc - median crest

mcr - midcranial ridge

mdr - median ridge of mesosternum

mr_2 - marginal ridge of mesosternum

mr_3 - marginal ridge of metasternum

MSU - Mississippi State University, State College (M. F. Schuster)

mt - mouth tubercle

ocs - ocular sclerite

OSU - Oklahoma State University, Stillwater (W. A. Drew)

pa - postalare

PAW - collected and mounted in balsam by P. A. Willoughby

pcr_2 - precoxal ridge of mesothorax

pcr_3 - precoxal ridge of metathorax

pdgt - posterior tarsal digitule

plr_1 - propleural ridge

plr_2 - mesopleural ridge

plr_3 - metapleural ridge

pn_2 - postnotal sclerite of mesothorax

pna - postnotal apophysis of mesothorax

pocr - post ocular ridge

por - postoccipital ridge

pra - prealare

prn - pronotal sclerite

pro - process of penial sheath

procr - preocular ridge

prsc - prescutum

pscr - prescutal ridge

prnr - pronotal ridge

pscs - prescutal suture

pudgt - posterior ungual digitule

rad - radial vein

scl - scutellum

sclf - scutellar foramen

sct - scutum

SEM - Snow Entomological Museum, University of Kansas, Lawrence (G. W. Byers)

ser - subepisternal ridge

sp_2 - mesothoracic spiracle

sp_3 - metathoracic spiracle

st - genital style

stn_1 - prosternum

stn_2 - mesosternum

stn_3 - metasternum

tar - tarsi

tds - thorax dorsal setae

teg - tegula

tib - tibia

tr - trochanter

UGAES - University of Georgia Agricultural Experiment Station, Experiment (H. H. Tippins and J. O. Howell)

USNM - United States National Museum of Natural History, Washington, D. C. (L. M. Russell and D. R. Miller)

vhs - ventral head setae

VPI&SU - Virginia Polytechnic Institute & State University, Blacksburg (M. Kosztarab)

vse - ventral simple eye

I. INTRODUCTION

Chionaspis americana Johnson and Chionaspis kosztarabi Takagi and Kawai are two scurfy scale insects which are native in North America. They predominately infest elm and ash trees respectively. Both species are bivoltine, and may produce large populations quickly. Typical scale insect damage occurs in loss of vigor, and aesthetic value often resulting in the death of branches and young trees.

Douglass (1909) stated C. americana was one of the most serious pests of elm, and Davis (1910) listed it with Lepidosaphes ulmi as the most destructive and most important scale insect in the Chicago area. Need of a more complete understanding of C. americana's biology is indicated by frequent control requests from the public and by common interception in nursery inspections. C. kosztarabi's absence from nursery inspection records is not due to lack of importance but because it was not recognized as a distinct species from C. gleditsiae until 1967. Elm and ash trees are popular and important ornamental trees in the United States and biological information of their major scale pests to define appropriate control would be highly desirable.

Johnson (1896b) described the adult female of C. americana including a few biological notes. Subsequent workers added little to his original description. Morphological descriptions and illustrations were confined to the adult female and included only pygidial characters. Takagi and Kawai (1967) described the adult female and second instar male of C. kosztarabi, but did not discuss its biology.

The research was undertaken on these two scale insect species with

the following objectives: to determine: 1) the seasonal life history and development, 2) natural enemies, 3) host range and distribution and 4) external morphology of all instars.

II REVIEW OF LITERATURE OF CHIONASPIS AMERICANA JOHNSON

Taxonomy and Morphology

The genus *Chionaspis* was established in 1869 by Signoret and placed in the coccid family Diaspididae, tribe Diaspidinae. Twenty-six species were included by Borchsenius (1966) in his world catalogue of armored scale insects. The genus is world wide in distribution though most of the species seem to be limited to specific geographic areas. Ferris (1937) recognized 12 North American species and Takagi and Kawai (1967) listed 17 belonging to North America, not including *C. wistariae*, which occurs here but was introduced from Japan. A wide range of host plants are infested in the United States. Some species have both bark and leaf infesting forms which caused confusion in the taxonomy of the genus in the past.

Chionaspis americana was first recognized and named by Johnson (1896a) and a description of pygidial characters published (1896b). King (1899) referred to the scale on elm as *Chionaspis furfurus* var. *ulmi* Ckll. Later workers, Cooley (1899), Hunter (1900), Sanders (1904), Herrick (1911), Dietz and Morrison (1916) followed Johnson, by including the species in *Chionaspis*. In 1921 MacGillivray transferred *C. americana* to his new genus *Fundaspis*. However, little regard was paid to the transfer by Britton (1923), and Hollinger (1923), and then Ferris (1937) firmly established the species as belonging to *Chionaspis* in his Atlas. Since then other workers, McKenzie (1956), Davidson (1957), Kosztarab (1963), Dekle (1965, and Borchsenius (1966), have agreed with Johnson's and Ferris's classification. Lindinger (1932) lists *Jaapia americana* as

a synonym of C. americana.

According to Borchsenius (1966) the taxonomic position of Chionaspis americana is as follows:

Order: Homoptera

Family: Diaspididae

Tribe: Diaspidini

Subtribe: Chionaspidina

Genus: Chionaspis

Species: americana Johnson

Cooley (1899) believed that the closest species related to C. americana was C. caryae and the two could be distinguished by the median lobes. On C. americana they are notched and on C. caryae they are entire. Balachowsky (1954) found C. americana similar to his European species C. lepinenyi and based the differences between the two primarily on the character of the median lobes and the dorsal micro- and macroducts. Takagi (1969) described a new species, C. floridensis, found on Fraxinus distinguishing it from a C. americana recorded from this host and from the "authentic" C. americana on Ulmus and Celtis. The two species are closely related; the only distinct external morphological difference is the presence of a submedian group of macroducts on the sixth abdominal segment on C. floridensis which are absent from C. americana. A secondary distinction is that the new species has more numerous dorsal macroducts than C. americana.

Biology

The original description by Johnson (1896b) included the most extensive work on the biology. He measured and described the female test

as follows: 2 to 3 mm long and 1.5 to 2 mm wide; and the male test, 0.73 mm long and 0.30 mm wide; eggs purplish, 0.22 mm long and 0.15 mm wide; crawlers, 0.22 mm long and 0.13 mm wide; and length of adult male from 0.25 mm to 0.35 mm. Later writers confirmed Johnson's records adding the number of broods per year in their area and occasionally including hatching dates and egg counts. Herrick (1911) noticed that when C. americana interspersed with a Targionia species it was somewhat smaller than usual measuring 1.6 mm to 1.8 mm long. Johnson provided, along with his measurements general body appearance, color, and a sketch outline of these stages without detailed taxonomic characters. He noted that the species was bivoltine in Illinois and overwintered in the egg stage. The first generation hatched about May 1 and the second about July 1. Cooley (1899) reported the first brood hatched in May in Amherst, Massachusetts as they did in Ohio (Sanders, 1904, Kosztarab, 1963) and Davis (1925) gave the hatch date as April 30 in Lafayette, Indiana. Kosztarab (1963) also observed that second brood eggs were present on July 16, 1961 in Pickaway Co., Ohio. Hollinger (1923) reported that there "appears to be at least three broods in Missouri". Reports in the literature showed a variation in average egg counts from 57 to 105; Johnson (1896b); Cooley (1899); Girault (1909); and Kosztarab (1963).

The use of temperature accumulation as an index to insect appearance was studied by Glenn (1931) mainly on the codling moth but the results obtained were used on other insects, including C. americana. Glenn stated that crawlers of the first brood might be expected after an accumulation of 275 day degrees and from the second brood after an accumulation of 1500 day degrees of effective temperature. To compute the

days degrees of effective temperature, Glenn used the formula $x = a - 2b$ in which "a" is the average of hourly temperature for the day above 50°F and "b" is the average of the hourly temperatures for the day above 88°F.

Treatment of the adult male was confined to the description of its test (Johnson, 1896b) and observations that a dimorphic condition was present finding a "pseudoimago" and an "imago". Few morphological differences existed between the two forms. The winged male form had well developed wings extending beyond the abdomen and fully developed halters. The nonwinged male form had short wing stubs and short stout halters without the terminal hook. During a single season's observation, Johnson (1896b) found that the nonwinged form was more numerous than the winged. He also observed that females attacked only the trunks and branches while the males were most abundant on the trunk and leaves, although also found on branches. Males are found primarily on the under surface of the leaves (Johnson, 1896a). Hollinger (1923) attributed a significant amount of the economic damage caused by this species to the yellowing and destruction of leaves by the large number of males infesting the leaves.

Studies of other stages, habits, and the seasonal life history of the elm scurfy scale have not been reported.

Natural enemies

The chalcid parasites, Perissopterus pulchellus (How.) and Physcus varicornis (How.) were both collected from samples in Illinois (Johnson, 1896b; Girault, 1911) and in Ohio (Houser, 1918). Girault (1913) also listed Signiphora pulchra Girault as a new chalcid species attacking this scale insect in Illinois. Three species of Eulophidae, Aphytis

diaspidis (How.), Marietta sp., and Prospaltella sp. were reared by Kosztarab (1963) who recorded 84% parasitism from collected specimens in Bond Co., Ohio on May 25, 1961. A single dipteran parasite, Leucopis nigricornis Eggers, was recorded by Schumacher (1919) and Fulmek (1943). The only predators recorded were the coccinellid, Chilocorus bivulnerus Muls. feeding on the insects, an unidentified mite among the eggs, (Johnson, 1896b) and a chickadee observed by McAtee (1926) pecking at female tests. According to his observations Johnson (1896b) believed that the parasites and predators were trivial agents in keeping this species in check.

Host and Distribution

Johnson (1896a) described C. americana from white elm, Ulmus americana, in Champaign, Illinois. He found the insect distributed throughout the state on ornamental elms and on virgin timber and so named it believing it was a native American insect. The most common host is the American or white elm, Ulmus americana. The insect infests its twigs, branches, trunk and leaves wherever it occurs in the United States. Other, less frequently attacked hosts than U. americana, have been recorded are listed as follows:

Benzoin odiferum: Amos (1933)

Celtis sp.: Herrick (1911); *Ferris (1937); Kosztarab (1963); McDaniel (1971)

Crataegus coccinea: Dietz & Morrison (1916); Merrill & Chaffin (1923)

Cydonia sp.: Hartman (1916)

Malus sp.: Herrick (1911); Hollinger (1923); McDaniel (1971)

Melia azedarach: McDaniel (1971)

Morus sp.: McKenzie (1956)

Platanus occidentalis: Kosztarab (1963)

Ptelea trifoliata: Hollinger (1923)

Ribes sp.: Hollinger (1923)

Ulmus campestris: Lawson (1917)

U. crassifolia: McDaniel (1971)

U. fulva: Newell (1899); Barber (1911); Lawson (1917)

U. moline: Sleeman (1945)

U. montana var. camperdown pendula: Cooley (1899); Houser (1918)

U. scabra pendula: Houser (1918)

*Ferris studied specimens on this host from Texas which differed in submedian pore pattern from the typical specimens, but because of the similar pygidial margin he believed Celtis specimens were but a variation of the same species.

The distribution of the hosts seem to indicate that C. americana occurs typically in eastern and central United States. In the east Cooley (1899) found it throughout Massachusetts. Felt (1905) found it "very abundant and destructive to a certain extent" in New York. Britton (1923) recorded it from several counties in Connecticut. In the central part of the United States it is widely distributed from the type locality in Illinois (Johnson 1896a,b) southward through the states to Texas; Dietz and Morrison (1916) found it over the entire state of Indiana; Saunders (1904), Houser (1918) and Kosztarab (1963) recorded it throughout Ohio; Hunter (1900) and Lawson (1917) found it common in Kansas; Newell (1899) called it "abundant" in Iowa; Hollinger (1923) recorded it in "practically every section" of Missouri and Herrick (1911) found

infestations in Missouri and from Texas as did McDaniel (1971). From a few other localities limited infestations were reported: Lugger (1902) found it in St. Paul and Minneapolis, Minnesota though "not very destructive at present"; Merrill and Chaffin (1923) recorded a slight infestation in Palatka, Florida; and McKenzie (1956) listed three California county records, Los Angeles, Orange and San Diego.

III. REVIEW OF LITERATURE OF CHIONASPIS KOSZTARABI TAKAGI AND KAWAI

Takagi and Kawai in 1967 completed a comparative study of the two Diaspididae genera *Chionaspis* and *Phenacaspis*. In the course of this study they recognized a new species, *Chionaspis kosztarabi*, as being distinct from the closely related *C. gleditsiae*. The new species was described and diagnostically distinguished from *C. gleditsiae* for both the adult female and the second instar male. Morphological descriptions and illustrations were included for the two stages. No biological data was provided. The host list included only *Fraxinus americana*, *F. nigra* and *Fraxinus* sp. No subsequent studies have been undertaken on this species.

IV. MATERIAL AND METHODS

Area of Study and Material

Chionaspis americana and *Chionaspis kosztarabi* occur in several localities on the VPI&SU campus. Heavy infestations were located which supplied weekly samples for a seasonal study of *C. americana*, and for biological observations on *C. kosztarabi* and individuals for a morphological study of both species. Ash, *Fraxinus americana* supporting populations of *C. kosztarabi* occur on the northeast side of campus in front of Brodie, Rasche and Shultz Halls. This site was sampled weekly throughout the summer, May 27, 1972 to November 7, 1972. Three well separated areas of *Ulmus americana* were located from which to collect *C. americana* samples so that data utilized in the life history would not be drawn from one tree or area. The first collection site and the one supporting the heaviest population was a single tree in front of the Police Department just north of campus. Site two was a large groove of elm trees on southeast campus located near the gymnasium and behind Eggleston Hall extending east to Donaldson Brown Center. The third site was a large old elm in front of Price Hall.

Each locality during 1972 provided specimens for Canada balsam mounts for descriptions and illustrations. To ensure that the study incorporated the range of structure variation and host distribution, slides and dry material were borrowed from several institutions in the United States. The sources of this material is listed under "Acknowledgements" and "List of Abbreviations Used". Borrowed material was returned and slides from Blacksburg, Virginia retained in the VPI&SU collection and

in the personal collection of P. A. Willoughby.

Sampling

Weekly observations were made on the populations of the two species from May through November 7, 1972. During the overwintering period the population was monitored by monthly samples. Collections at each site were obtained with the aid of garden clippers and a long handled tree trimmer. Branches and twigs were clipped at random until there appeared to be adequate material from each site for study. Each sample was taken to the laboratory and examined under a binocular microscope. The first 33 to 35 live, non-parasitized C. americana individuals were obtained from each of the three sites until a total of 100 specimens were slide mounted in Hoyer's media. Specimens were examined microscopically to determine the percentage of the population in each life stage. The number of parasitized stages found while obtaining the 100 specimens was recorded for calculating the percentage parasitism. Other specimens were preserved in 70% alcohol later to be used in stain mounted slides. Weekly samples of live C. kosztarabi were also mounted in Hoyer's and preserved in 70% alcohol but no attempt was made to obtain a specific number of individuals.

Rearing

Freshly collected, heavily infested twigs from each weekly sample were placed in cellophane bags and sealed with paper clips to rear parasites and males for each species. The bags were checked weekly under a binocular microscope and the emerged individuals removed and placed in 70% alcohol. Parasites were sent to B. D. Burks (USDA) for determination and males were preserved in 70% alcohol for later slide preparations.

Predators

Mites observed in direct association with the two Chionaspis species were directly mounted in Hoyer's medium. Mounted mites were sent to E. W. Baker and R. L. Smiley (USDA) for identification. Examination was also made of collected field specimens for predators other than mites.

Fecundity

The fecundity of C. americana was determined by egg counts. When it was observed that oviposition had been completed at least 10 females from each of the generations were selected at random. The test was carefully lifted and the contained eggs were allowed to spill into a petri dish filled with tap water. The eggs were then counted under a binocular microscope.

Color Coding

Live material was placed on a glass slide and the color compared with the hues in the 1965 edition of Munsell's Book of Color. The color description was recorded for each stage.

Mounting Methods

The biological and morphological study required detailed observations of slide mounted specimens under a phase contrast microscope. Each of the two different mounting methods was found to offer distinct advantages for the two phases of the study.

The biological study utilized almost entirely the specimens mounted in Hoyer's medium. This procedure was simple, fast, and did not alter the specimen during chemical preparation. Live scale insects were placed directly on a small droplet of Hoyer's on a glass slide. The mounts were then placed in a 40°C warm oven until dried. The first hundred specimens

from each weekly sample were mounted in this manner. At a later date the life stages could be determined and rechecked. Mouthparts and other structures were intact as taken from the plant material; the value of this for the biological study was significant. For example an entire stylet on a first instar indicated the "crawler stage", while a broken stylet indicated the "settled crawler", and a coiled stylet indicated molting. The Hoyer method was also of great use in the morphological study for determining setal arrangement and for measuring structures. The formula used to prepare Hoyer's mounting media was as follows:

Distilled water	50cc
Gum arabic	30g
Chloral hydrate (crystals or powder)	200g
Glycerine	20cc

The morphological study required microscopic examination of slide material stained for taxonomic detail and mounted in Canada balsam. This necessitated chemical processing during which body contents are cleared and the specimen is stained and slide mounted. The number of times the specimen needed to be handled during clearing, dehydration and staining often resulted in structure injury or breakage. The most satisfactory results are obtained when live fresh specimens are used. Specimens are removed from the plant material directly into 70% alcohol where they remain for at least 2 hours prior to mounting.

The following basic method, a modification of Wilkey's (1962) Method, was used for all life stages with a few alterations noted for first instars.

1. A small incision was made in the body wall of adult females, and usually the males, while still in alcohol. This step was omitted from other stages.

2. Specimens were transferred to 10% KOH and heated gently at 300°F until body contents began to clear. This generally occurred within 15 minutes to 1 hour.

3. Specimens were transferred to Essig's Aphid fluid and heated at 250° to 300° F until the specimen was transparent.

4. A few drops of stain were added to the Essig's Aphid fluid or the specimens were transferred to a dish of clean Essig's Aphid fluid and the stain added.

5. The specimens remained in the stain at room temperature overnight or were heated at 300° F in the stain for 15 minutes.

6. The specimens were then transferred to 70% ethyl alcohol for 5 to 10 minutes.

7. The specimens were then transferred to clove oil for at least 10 minutes. Specimens could remain indefinitely in this solution.

8. The specimens were mounted in Canada balsam under a 12 mm round cover glass.

9. The slides were permanently marked with a diamond point pencil.

10. Slides were kept in a drying oven at 40° C for two weeks prior to labeling.

First instars required more delicate treatment. It was found that better slide mounts were prepared by omitting steps 2 and 6. They were cleared by heating at 200° F in Essig's Aphid fluid until clear; often this required more than 24 hours. First instars became brittle and crumpled when transferred from stain into 70% alcohol and therefore were placed directly from stain into clove oil.

The formulas used in the preparation of Essig's Aphid fluid and the

staining solution can be found in Howell and Kosztarab (1972).

Several of the type slides were in unsatisfactory condition for microscopic study. These were released by immersion in xylene and remounted by reversing the above procedure.

Measurements and Illustrations

Measurements were taken from 10 mounted specimens wherever possible, where other than 10 specimens were used it is stated in parenthesis. Measurements are given in microns unless otherwise designated and were obtained by using the ocular micrometer on a Zeiss R A phase contrast microscope. The range of magnification used was 35X to 2000X. Morphological characters of taxonomic importance were measured and the average given followed by the range in parenthesis. When a taxonomic character showed variation in number per individual, the same form was followed, the average of 10 specimens followed by the range in parenthesis. To define the range of variation in character size and character number, an effort was made to include specimens from various sections of the country and from different hosts.

The male measurements were handled somewhat differently. It was felt that the chemical treatment of Canada balsam preparation caused shrinkage in size and often distortion of characters. Therefore, specimens mounted in Hoyer's medium were used for measurements of body regions, the segments of the antennae, and leg appendages. Stained Canada balsam mounted specimens could be used for measurement of setae and heavily sclerotized thoracic structures.

Drawings of all stages were made by using slide mounted specimens enlarged by the Leitz Prado 500 microslide projector. Details were added

from study under the Zeiss phase contrast microscope. Each figure had a central drawing for the whole specimen with the left half representing the dorsal surface and the right half the ventral surface. The central drawings and details are not drawn to the same scale in all species since it is more advantageous to use the available space most economically. The structures within the central drawing express character distribution and placement and are not necessarily drawn to scale with the entire drawing. Therefore, when questions concerning size arise reference should be made to the measurements given in the text.

The terminology used for the female stages, first instars and second instar males was adapted from Ferris (1938), Balachowsky (1954), and Kosztarab (1959). Ghauri (1962) was used as a reference for prepupal, pupal and adult male terminology.

Material Studied

The section "Material Studied" lists the actual slides included in the range of measurements and character number. For each slide the first number indicates the number of slides, the second number in parenthesis the number of specimens from the same lot, the remaining designations in order are as follows: locality collected, collector, date of collection, depository and slide number or numbers. This information was included for those stages where time of collection would probably indicate presence as live individuals at that locality. Such data on adult female slides was not considered significant as this stage can usually be collected at anytime during the year as dead dried material from previously occurring generations.

V. RESULTS AND DISCUSSION

A. BIOLOGY OF CHIONASPIS AMERICANA

Life History

Chionaspis americana is bivoltine in Montgomery Co., Virginia, overwintering as eggs and gravid or spent adult females. The seasonal life history is shown in Table I giving the percent of individuals in each sample. The active period of the elm scurfy scale extends from the hatching of the eggs in April to oviposition by fertilized females in October. A few females remain live during the winter but the majority die in the fall and the winter is passed in the egg stage.

Climatological data for the Blacksburg area was obtained from the U. S. Department of Commerce. Table II shows the period when the median 50% of each life stage was present. The number of days duration of this period for each stage is noted in column 2. Duration of stages is inversely related to temperature.

Egg

Following oviposition, the eggs are contained under the adult female test. They are reddish-orange in color, 10R/6/8, elongate-oval in shape with one end slightly smaller than the other, and measure about 2 mm X 1 mm in size. The eggs change in appearance during development. From the time the overwintering eggs are laid until about a month prior to hatching they are marbled red and white in appearance. When mounted in Hoyer's mounting medium they are without recognizable surface structures. Two changes indicate the maturing of the hibernal eggs. First, the eggs loose their "marbled" appearance and become uniformly red in

Table I

PERCENT OF Chionaspis americana Johnson INDIVIDUALS IN EACH STAGE OBSERVED IN EACH WEEKLY SAMPLE AT BLACKSBURG, VIRGINIA

Stage	GENERATION I														GENERATION II									
Adult Female							1	10	72	97	95	36	13	3					3	42	42	70	94	100
Adult Male								2	13										1	15	8	7		
Male Pupa								18	7										10	24	26	13	3	
Male Prepupa							3	12		1									10	3	2	2		
Molting Second Stage Female								24	3										15	1	7	2	1	
Second Stage Male					3	17	36	15	4	2						14	42	52	34	7	8	4	2	
Second Stage Female					9	70	59	18	1							13	47	46	27	8	7	2		
Molting Settled First Stage					20	6	1	1						2		13	3							
Settled First Stage		34	70	80	52	4								44	80	55	8	2						
First Stage	33	57	19	18	16	3								22	12	4								
Egg 100	67	9	11	2							5	64	87	29	8	1								
Collection Date 1972 - Month / Day	4/13	4/26	5/2	5/9	5/16	5/23	5/30	6/6	6/13	6/20	6/27	7/4	7/11	7/18	7/25	8/1	8/8	8/15	8/22	8/28	9/5	9/12	9/19	9/26	10/3

Table II

AVERAGE MAXIMUM AND MINIMUM TEMPERATURE DURING PERIOD WHEN THE MEDIAN 50% OF EACH LIFE STAGE WAS PRESENT IN BLACKSBURG, VIRGINIA

	Generation I				Generation II			
Stage	Median 50% of each Life Stage	Duration in Days	Average Maximum Temperature	Average Minimum Temperature	Median 50% of each Life Stage	Duration in Days	Average Maximum Temperature	Average Minimum Temperature
Egg	IX-10-72 to V-07-73	178	50.2	27.4	VII-06-72 to VII-26-72	21	81.0	57.9
First Instar	IV-24-72 to V-26-72	32	68.0	42.4	VII-21-72 to VIII-14-71	25	80.9	59.4
Second Instar	V-24-71 to VI-13-72	20	72.8	43.8	VIII-08-72 to IX-02-72	26	80.8	58.8
Male Pupa	VI-10-72 to VI-23-72	13	73.7	52.9	VIII-08-72 to IX-12-72	23	77.3	51.0
Adult Male	VI-17-72 to VI-23-72	6	70.9	58.4	IX-01-72 to IX-12-72	12	75.3	47.7
Adult Female	VI-13-72 to VII-15-72	33	74.7	53.3	VIII-28-72 to IX-04-72	69	69.2	44.0
Oviposition	VII-06-72 to VII-15-72	9	76.6	53.4	--	--	----	----

color. During the last week of development, the embryo shrinks away from the chorion at the anterior and posterior ends and black eyespots are visible through the chorion. In specimens mounted in Hoyer's medium, structures of the 1st nymph can be distinguished, the mouthparts are coiled at each side of the head, antennae and legs are bent back extending submedially on the ventral surface, and slight segmentation lines on the abdomen are distinct. The developmental changes in the eggs of the second generation occur rapidly during the two week time lapse between oviposition and hatching.

First Instar

The first C. americana eggs had hatched by April 20, 1972 and April 30, in 1973; the second generation had begun hatching by July 25, 1972. First generation eggs were present until May 16, 1972 and second gener. eggs through the first week of August. Crawlers emerge head first from the egg through a split in the anterior one-half of the chorion which extends either medially or along the lateral margins. Then they may or may not crawl out from under the parent female test. The first instar nymphs upon emergence are ovoid, about 0.25 X 0.15 mm in size when mounted on a slide, and red in body color, 7.5R/4/10, with white opaque appendages. Observations of crawler movement on a white index card showed they moved apparently at random about 14.3 (range of 9 to 21) mm per minute. When crawling the long anal setae drag straight behind, the curved stylets are held flattened on the ventrum, the antennae are held at a 45° angle constantly tapping the surface, and under high magnification the long ventral cephalic setae appeared to extend forward in contact with the substrate. Crawlers remain active from a few hours to

several days. Upon finding a suitable feeding site active movement ceases, the legs are drawn in upon the ventrum and the stylet is inserted into the plant material and feeding begins. The first crawlers from generation I seemed to remain under the adult female or to settle under other nearby old female tests of the same species and occasionally crawlers were found under soft scales (Coccidae) and oyster shell scale covers. As hatching progressed other more exposed sites were selected on the twigs of previous year's growth, and near bud bases on the green tender twigs of current growth. Their color changed from red to orange or orange-yellow and as the nymphs fed they increased in size becoming more oval. First instar nymphs measured about 3 mm X 2 mm at molting. Shortly after settling wax for test formation is secreted from the lateral areas of the body until the posterior region is covered at the time of the first molt. No ventral cover seemed to be formed at this stage. Large strands of wax, observable as a tangled mass of strands, issue from the large ducts in the head between the antennae. These are later sloughed off and do not seem to be incorporated into the test structure. The first wax cover usually is sloughed off at molting and does not comprise part of the second instar test.

First Molt

The dorsum of the first instars becomes chitinized and hardened as development progresses. About two weeks after emergence from the egg, molting takes place. Mouthparts of the second instar coiled at each side of the mouthpiece of the first instars indicate that molting is about to occur. This pre-molting condition is easily distinguishable on specimens mounted in Hoyer's medium. At ecdysis, the thin membranous

ventrum splits just posterior of the antennae and the ventral skin is pushed caudad so that the legs and mouthparts are seen at the anal end of the cast exuviae and the antennae are positioned at the anterior margin. The newly emerged second instar is then completely covered by the first exuviae. Molting was first observed in 1972 on May 23, and July 25; all were second instars by June 6, and August 22, for the two generations respectively.

Second Instar

The newly emerged second instar is entirely membranous, oval in shape and entirely protected under the chitinized first exuviae. After molting to second instars, the two sexes can be distinguished under low power magnification without removing them from the host by differences in shape and sclerotization, pygidial lobes, by test construction and by areas of occurance on infested material.

FEMALES: They increase in size and differentiate in shape at this time. The posterior area of the body becomes longer and wider with the widest area occurring 2/3 of the distance away back from the head. The narrow head remains under the first exuviae. Small black eyespots occur on the head, slight segmentation lines are visible on the abdomen, prominent median pygidial lobes can be distinguished, and the pygidial area is slightly sclerotized a shade darker in color than the rest of the body. Gradually the dorsum becomes chitinized turning a shiny bronze. Wax is secreted dorsally from the abdominal margin forming the pearshaped white waxy test as the female develops. Small glands on the ventrum form a very thin, nearly transparent ventral cover. The body color gradually deepens from yellow-orange, 2.5YR/6/8, to yellow-brown, 5YR/6/8.

Females are found on the bark of twigs and at the bases of buds and rarely one will be on the leaves. Second instar females in 1972 were first observed on May 23 and for second generation, August 8; all had molted to third instars by June 27, and September 26, respectively.

MALES: At first the oval males enlarge their body mainly in length, becoming very elongate-oval at the completion of the second stadium. The body remains entirely membranous, black lateral eyespots are present on the head, and the rounded pygidium is without obvious lobes. The dorsum does not become sclerotized from exposure as wax glands on both body surfaces secrete a frosty white test both ventrally and dorsally. The dorsal surface of the test is tricarinate, the texture is flaky and is somewhat thicker dorsally than ventrally. About midpoint of the second stadium an exit flap is formed for adult male emergence. This consists of lateral slits at the posterior 1/3 margin on each side of the test; this portion is thinner than that which covers the body. At completion of the test, the male is anchored to the plant material only by the first exuviae and stylets and is completely enclosed by the white elongate test. First generation males can be found in equal numbers on the under surfaces of leaves or on the bark of twigs and branches. Males from the second generation are almost exclusively found on the leaves. Preference is usually shown for the undersurface of the leaves. From a sample on August 28, 1972 a total of 101 tests were counted on the undersurface while only 21 were observed on the upper surface. Leaves examined showed a range of 0 to 12 male tests per leaf. Leaf feeding usually produces a light yellow discoloration which encircles the area of attachment. Second instar males were collected in 1972 from the first

generation on May 23 and from the second on August 8; all had molted by July 4 and October 3, respectively.

Second Molt

The molting procedure is the same for the second instar females as it was for the first instars; the membranous ventrum splits anteriorly and is pushed posteriorly resulting in the mouthparts laying at the anal end. The second exuviae are covered by the white wax secreted by that instar and the new third instar female's narrow head fits under the first exuviae and the remaining body under the second. Molting of the second instar males is somewhat different. The membranous skin splits caudally as it is pushed forward and lays crumbled at the anterior region of the test. It is not incorporated into the male test.

Male Prepupa

After the second molt males enter the prepupal stage; mouthparts are absent and no further test enlargement occurs. Male prepupae are easily distinguished from the other male stages as live specimens; they are spindle-shaped, without a projecting anal area, and developing appendages are not apparent except for short antennal sacs compressed laterally at the head region. The color darkens to a deeper red and a large pair of black eyespots are located on the head region. The prepupal stage is short lasting but a few days. They were observed in generation I June 6 to June 27 and for generation II first collected on August 28, with a few present until September 26.

Male Pupa

Development from prepupae to pupae continues without a concurrent molt. The two stages are easily distinguished. First, pupae have a

prominent projecting last abdominal segment which is absent from pre-pupae. Later, the developing appendages, located laterally, on pupal males can readily be observed. Much differentiation occurs during this stage. Pupae become more "insect" like with increased development of distinct body regions, wings or wing stubs arise within wing pads, faint abdominal segmentation lines form and the dorsal and ventral simple eyes become visible as distinct black eyespots. Pupae were present June 13 to June 27 for generation I and August 28 to September 26 for generation II.

Adult Male

Adult males were present June 13 to June 27 and August 28 to October 3, 1972. Males are deep red in color, 2.5YR/4/8, have prominent black eyespots on their head, are bushy in appearance due to the many long setae on the surface of the legs and antennae, and have a very long thin stylet projecting from the anal end. Two forms were collected, apterous and brachypterous. Fully developed wings are held flat on the dorsal surface extending beyond the abdomen. Other males appeared wingless but slide preparations showed the presence of short wing stubs. Adult males and pupae mounted in Hoyer's medium and Canada balsam were analyzed to determine the frequency of each condition. From a total of 259 individuals recorded from the two generations, 83 were apterous and 176 were brachypterous. Males emerge by backing out of their test through the posterior slits. Upon emergence adult males are very active. They were observed running quickly on leaf and twig surfaces searching for suitable females. Males do not feed during their short life span of several hours to one day.

Adult Female

Adult females were first present in 1972 on June 13 and August 28 and all second instar females had become adults by July 27 and September 26 for generations I and II respectively. Young females deepened in color with age to dark orange, 7.5YR/7/8, and finally dark red, 7.5R/4/10, as eggs developed internally. Black eyespots could be detected throughout development. Wax secretion continued from the dorsal glands on the posterior of the abdomen, enlarging the test until oviposition occurred. The white test often became gray to black as particles of bark and dirt adherred to it. Ventrally a thin wax cover was present and a fine white powdery wax clump at each spiracle could be detected.

Oviposition

Females were observed enlarging their test caudally until the time the first eggs were deposited. No exit flap for crawler emergence seemed to be formed. After mating some physiological changes were observed preparatory to oviposition. The once light red females deepened in color. Ova first formed in the cephalic region gradually developing posteriorly until the entire body contents had been converted to eggs and the color was a very deep red or rust. Several days before oviposition begun a white powdery secretion was observed at the vulva coating eggs. The dermal wall in front of the vulva contracted folding the ventral surface while the dorsal surface remains extended in the normal postion as oviposition begun. Egg deposition results in female physiological suicide. Eggs are laid single. The first eggs are deposited at the posterior area of the test. As the ova is secreted the female folds from the posterior end to the cephalic end moving forward until com-

pressed in the most anterior test region and the remainder is filled with the egg mass. The eggs are packed several layers high near the female body and thin out posteriorly. For the first generation the process occurs rapidly, the first eggs were observed July 4 and by July 18, 86% of the females examined had laid a few to many eggs. A week later only 4 females were living. However, the second generation egg laying spanned a longer time interval. A few eggs were found under females on October 3. By October 31, 56% of the females had deposited eggs and by November 7, 81% had laid eggs. A few females remained alive during the winter months supposedly still depositing eggs. I found in January and February many soft bodied, deep red females, some with deposited eggs, others without eggs. From a sample taken on March 30, 1973 a total of 160 females were counted, 130 were dried and dead and the remaining 30 were alive with a powdery white secretion at their pygidiums indicative of continuing oviposition. Table III expresses the egg number counted under at least 10 individual females in each of the three observed generations.

The occurrence of males in the population indicated male fertilization. To determine if parthenogenesis occurred when females were not fertilized, individual females of generation II were isolated before male emergence on small pieces of twigs and placed in cotton stoppered vials. In November these females were examined for oviposition. No eggs were found. All were dead and compressed at the anterior test area like females which had oviposited. The tests of these females were fully developed. It can therefore be assumed that probably fertilization is necessary for egg development.

Table III

FECUNDITY OF *Chionaspis americana* Johnson
IN BLACKSBURG, VIRGINIA

	Number of eggs per female on *Ulmus americana*		
Sample	March 30, 1972	July 18, 1972	February 28, 1973
1	80	82	59
2	84	79	74
3	50	19	65
4	71	97	68
5	55	78	99
6	87	68	83
7	92	102	95
8	67	128*	55
9	36	50	34
10	41	43	122
11	39	132*	
12	92	63	
13	101		
Average	69	78	75
Range	36-101	19-132	34-122

* Egg counts taken from adult females settled under old *Lecanium* sp.

B. NATURAL ENEMIES

Parasites

Infested twigs containing an undetermined number of Chionaspis americana were collected weekly during the summer at each of the three Blacksburg sites. These samples were first examined to remove other occurring scale insect species from the twigs and then were placed in cellophane bags and examined weekly for parasite emergence. A total of 336 parasites were reared, collected and sent to B. D. Burks for identification. Table IV gives the parasite species found infesting C. americana. Peck's (1963) C. americana host list includes two of these parasites, Marietta pulchella (Howard) and Physcus varicornis (Howard) and one additional species, Thysanus pulcher Girault, not collected in Blacksburg, Virginia.

A total of 13 hymenopterous parasite species and one hyperparasite, Marietta mexicana (Howard), were collected belonging to two chalcid families. The most significant parasite group collected was determined as Aphytis sp., and comprised 75.9% of all the parasites reared from C. americana. They first began to emerge early in May and continued into October. Peak emergence occurred during the last week of July and the first week of August. Intermediate levels were observed during one week prior and one week after this period. Aphytis sp. so dominated the parasite population that it was the one on which nearly all the sample observations were made. The other parasites were insignificant in occurrance, except for perhaps Physcus varicornis (Howard) and the Aphytis proclia group.

The majority of the parasites found were external feeders though a

Table IV

HYMENOPTEROUS PARASITES REARED FROM C. americana IN 1972

Family	Species	Total No. Collected	Percent of Total
ENCYRTIDAE			
	Blastothrix longipennis Howard*	1	0.3
	Aphycus lounsburyi Howard*	1	0.3
	Aphycus pulvinariae Howard*	4	1.2
	Aphycus sp.	2	0.6
	Apterencyrtus microphagus (Mayr)	1	0.3
	Plagiomerus diaspidis Crawford	2	0.6
EULOPHIDAE			
	Aphytis sp.	255	75.9
	Aphytis proclia group	24	7.1
	Aspidiotiphagus citrinus (Crawford)	2	0.6
	Coccophagus lycimmia (Walker)	1	0.3
	Marietta mexicana (Howard) (hyperparasite)	9	2.7
	Marietta pulchella (Howard)	5	1.5
	Physcus varicornis (Howard)	28	8.3
	Prospattella elongata Dozier	1	0.3
Grand total of individuals		336	100.00

*This species is not known as a parasite of Diaspididae. We are assuming that they emerged from other insects, probably from soft scales accidently present in the sample.

few internal parasites were also observed. The larval stage of the parasite was first recognized on early third instar females and was present through the oviposition period. Parasites fed on the dorsal abdomen, often the scale insect appeared to be cut in two as body fluid was retracted centrally. Parasites were not observed on male specimens probably because males have insufficient body material for parasites to complete development. The effect of the parasite depended upon the age when the scale insect was attacked; a mature adult female scale insect parasitized by a late instar chalcid was killed or otherwise prevented from oviposition. However, early instar chalcid larvae were observed feeding on mature ovipositing females. Egg number was usually reduced but often fell within the normal range for the species. On July 18, 128 parasitized females were collected comprising 20 females with few to many deposited eggs and 108 females without eggs.

In the Blacksburg area in 1972 parasites seemed to be a major controlling factor affecting the population level of generation II. In a sample, collected on April 26, 1972, I found 22% of the 96 adult females parasitized. Generation I was examined for parasitism on July 18 when the scale insect population was comprised of ovipositing females prior to egg hatch. Of a total of 258 adult females observed, 62% were found infested with parasites. By October the majority of the scale insect population had reached maturity. On October 3, 23% parasitism was found and on October 17, 17% was recorded. Monthly samples of the scale insects during the winter months showed that many parasites remained in the larval stage, presumably feeding through January. A February sample yielded a few larvae and a few pupae. The percent parasitism, 22%, 23%,

17% for generation II and 62% for generation I is much lower than the 84% recorded by Kosztarab (1963) during May in Ohio.

Associated Acarina

Mites directly observed in association with Chionaspis americana by being under old scale insect tests, under female tests containing immature stages or with adult females were collected and sent to the USDA Systematic Entomology Laboratory for identification. The list identified by E. W. Baker and R. L. Smiley is as follows: Acaridae: Thyreophagus entomophagus (Lab.); Camisiidae: Nothrus sp.; Cheyletidae: Cheyletia pyriformis (Banks); Cymbaeremaeidae: Scapheremaeus sp.; Eriophyidae: undetermined; Hemisarcoptidae: Hemisarcoptes malus (Shimer); Phytoseiidae: Typhlodromus longipilis Nesbitt; Saproglyphidae: Czenspinskia lordi Nesbitt; Tarsonemidae: Tarsonemus smithi Ewing; Tydeidae: Tydeus sp.

Mites in the families Tarsonemidae, Cheyletidae, Tydeidae, Hemisarcoptidae, Phytoseiidae are predominately predators. Observation made on the collected mites indicate Tydeus sp. and Hemisarcoptes malus are important predators of C. americana. Many specimens of Tydeus sp. were collected throughout the summer among eggs, settled crawlers, first and second instars, and adult females. Tydeus sp. seemed to be the most important and the most frequently encountered mite associated with this scale insect. H. malus was found under female scale insect tests laying eggs simultaneously with ovipositing first generation scale insect females. Flattened scale insect eggs indicated that egg predation occurred. This mite species seemed to be highly significant in July, being recorded from many live egg masses but thereafter was not observed.

C. MORPHOLOGY OF CHIONASPIS AMERICANA JOHNSON

ADULT FEMALE

Plate 1

Chionaspis americana Johnson, 1896a:150; 1896b:390; 1896c:77; Cooley, 1899:41; Newell, 1899:152; Hunter, 1900:102; 1902:118; Lugger, 1902:238; Fernald, 1903:213; Sanders, 1904:43; Felt, 1905:207; Douglass, 1909:114; Girault, 1909:355; Davis, 1910:186; Barber, 1911:450; Girault, 1911:183; Herrick, 1911:23; Jarvis, 1911:71; Girault, 1913:189; Dietz and Morrison, 1916:264; Hartman, 1916:101; Lawson, 1917:260; Houser, 1918:290; Schumacher, 1919:305; Hollinger, 1923:19; Merrill and Chaffin, 1923:212; Davis, 1923:136; Britton, 1925:362; McAtee, 1926:87; Frison, 1927:158; Glenn, 1931:180; Amos, 1933:207; Ferris, 1937:SI-15; Fulmek, 1943:23; Sleesman, 1945:43; Ferris and Rao, 1947:27; Balachowsky, 1954: 326; McKenzie, 1956:93; Kosztarab, 1963:63; Dekle, 1965:32; Borchsenius, 1966:96; Takagi, 1969:269; McDaniel, 1971:282. Chionaspis furfurus var. ulmi Cockerell, King, 1899:335. Fundaspis americana (Johnson), MacGillivray, 1921:338; Ferris, 1936:54. Jaapia americana (Johnson) Lindinger, 1932:200.

Test: Oystershell-shaped, convex, white to dirty white as it is often coated with soot or particles of bark obscuring it from view. Measurements of 10 covers 2.40 (2.00-2.70) mm long, and 1.10 (0.70-1.40) mm wide at broadest area. Cover composed of terminal first exuviae, pale yellow 2.5YR/6/6, 1/8 of entire cover; and larger second exuviae, dark brown, covered by secreted wax. A white scar, the outline of the cover, is left when removed from the bark.

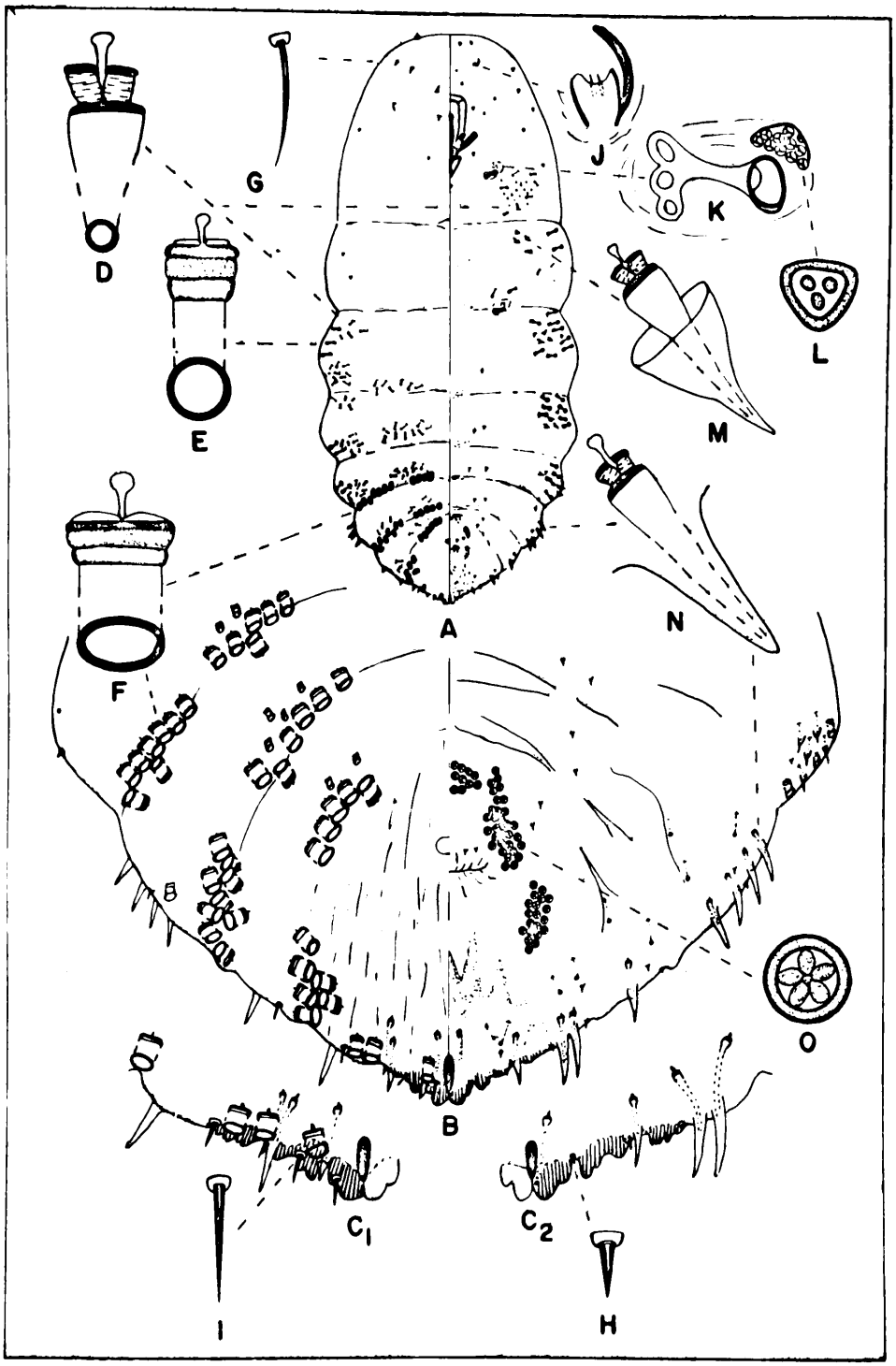

Plate I.- Chionaspis americana Johnson, adult female

DESCRIPTION

Body spindle-shaped (fig. A) to pearshaped, broadest at mesothorax, 1210 (749-1575) long and 635 (483-817) wide, margins lobed, color without eggs light orange 7.5YR/7/8, derm membranous except for sclerotization at pygidium.

Pygidial margin (figs. B, C_1 & C_2): Broadly triangular with prominent sclerotized lobes. Median lobes well developed 19.8 (14.8-24.7) long, closely appressed and may or may not be fused for more than half their length, rounded apically, notched on lateral margin, yoked together by club shaped basal zygosis. Second lobes conspicuous, bilobed, inner lobule notched laterally, outer lobule broadly rounded. Third lobe indistinct, reduced to small sclerotized projection. Gland spines, stout and tacklike setae and macroducts present.

DORSAL SURFACE

Microducts: One-barred microducts (fig. D), 9.55 (6.83-11.7) long and 1.77 (0.98-2.44) wide, 2 to 15 submarginally on each half of body segments I, II, III, often present as an anterior group and posterior group on each lobe or these ducts may be absent; typical specimens with submedian transverse rows of 0 to 38 on segments I, II, III and frequently few submedially on segments IV and V. Two-barred microducts (fig. E), 9.13 (6.18-12.4) long and 3.90 (2.47-4.94) wide, marginally, 2 to 4 on mesothorax, 8 to 20 on metathorax, and 4 to 20 on segments I, II, III.

Macroducts (fig. F): Two-barred, 13.2 (9.88-14.8) long and 7.41 (4.94-9.88) wide, arranged in submedian and marginal groups on each side of body, segments III, IV, and V as follows: submedian: III, 2 to 13 (6.05); IV, 2 to 11 (6.05); V, 2 to 7 (4.50); marginal: III, 4 to 11

(7.95); IV, 5 to 13 (9.48); V, 5 to 11 (6.31). Marginal macroducts not in groups: 2 on segment VI and 1 on segment VII.

Setae: Few slender hairlike setae (fig. G), 6.68 (4.88-8.78) long, at cephalic region. Short tacklike setae (fig. H), 1.25 (0.49-1.95) long, scattered on meso- and metathorax. Stout marginal setae (fig. I) 14.8 (12.7-20.5) long, 1 on each of segments V to VIII both side of the body.

Anal area: Anal opening circular 13.0 (9.88-17.3) in diameter, located ca. 8 times length of median lobes from pygidial apex.

VENTRAL SURFACE

Antennae (fig. J): Small sclerotized tubercles, 6.73 (4.88-8.78) long and 8.11 (6.18-9.88) wide at base, each antenna with 1 lateral fleshy seta, 17.0 (11.7-21.5) long, and 2 short terminal hairlike sensory setae, 3.54 (1.95-9.88) long. Distance between antennal bases 66.0 (44.5-104).

Clypeolabral shield: Length 129 (93.9-161); width 49.5 (37.1-61.8).

Labium: Shieldshaped, length 43.8 (31.1-64.2); width 48.2 (39.5-59.3).

Legs: Absent.

Spiracles: Anterior spiracle (fig. K) 25.3 (22.2-37.1) long, atrium 7.63 (7.41-8.65) wide, with 3 to 21 (11.3) associated trilocular pores at each spiracle (fig. L), pores 3.61 (2.93-3.90) in diameter; posterior spiracles similar in shape, slightly smaller, 23.5 (19.8-25.9) long, with 2 to 5 (3.25) associated trilocular pores at each spiracle.

Gland tubercles (fig. M): Conical basally becoming spinelike anteriorly, 14.1 (11.1-14.8) long and 5.43 (3.71-7.41) wide at base, with

associated one-barred microducts, submarginally in groups of 4 to 12 on meso- and metathorax and segments I, II, and 6 to 18 on segment III often marginal.

Gland spines (fig. N): Marginal gland spines, 28.3 (17.3-37.1) long and 5.10 (3.71-8.65) wide at base, with associated one-barred microducts located on each body side as follows: IV, 2 to 6; V, 1 to 2; VI and VII, 1 on each segment, occasionally fimbriated at tip.

Microducts: One-barred microducts (fig. D) 8.42 (6.83-11.7) long and 1.72 (0.98-2.44) wide, always present in submedian group of 20 to 31 basad each anterior spiracle, 1 to 2 at each posterior spiracle. Two-barred microducts (fig. E), 8.49 (7.41-12.4) long and 3.65 (2.47-4.94) wide at thorax increasing in size, 9.13 (7.41-11.1) at abdomen, marginally, few on meso- and metathorax, 4 to 30 on segments I and II, 0 to 10 on segment III.

Macroducts: Absent.

Setae: Long slender setae (fig. G) 7.79 (4.88-19.5) scattered on cephalic region. Short tacklike setae (fig. H) 2.38 (0.98-3.90) long, in two submarginal longitudinal rows along each side of thorax and abdomen, marginal rows segments VI to VIII, becoming stouter and longer (fig. I) on segment VI, 5.95 (4.88-7.81) long, and a paired submedian longitudinal row from segment II to vulvar opening.

Minute spinelike structures: Transverse medial rows extending from base of labium to apex of vulva.

Vulvar area: Vulvar opening on middle of pygidium; paravulvar sclerosis distinct. Quinquelocular perivulvar pores (fig. O) in 5 groups: median, 18 to 44 (24.5); anterolateral, 20 to 44 (28.4); and

posterolateral, 18 to 35 (23.1); each pore 4.65 (3.90-4.88) in diameter.

NOTES

A wide variation in pore patterns and pore numbers was recognized while examining the specimens on 220 slides obtained for this study. All females seemed to exhibit the distinctive form of the pygidium and were from Ulmus sp. except for 29 slides. After examination the lots were sorted into five groups. The first and largest group, 43 percent, exhibited a definite group of ventral one-barred microducts posterior to anterior spiracles; dorsal transverse rows of one-barred microducts, usually numerous, on abdominal segments I, II, III and few to many at submedian macroducts on segments IV, V and VI. The type specimen displayed these characters and therfore, this group was considered typical. The geographical range was wide but mainly confined to the northern midwest and the east coast: Minnesota and Illinois to Ohio, Kansas to Missouri and Mississippi, Rhoad Island through Virginia. Also included in this group were 1 slide from Celtis occidentals from Mississippi, and 2 slides from Crataegus sp. from Pennsylvania. The group of one-barred microducts at the anterior spiracle was present in the second group which comprised 31 percent of the material. However, on abdominal segments I, II, and III, 1 to 3 one-barred microducts were present on each body half but not arranged in definite transverse rows nor as numerous as in group I and these ducts were entirely lacking at the submedian macroducts. The geographical range of this group was also wide although more southern states were represented: Alabama, Texas, Oklahoma, Georgia, Mississippi, Florida, Tennessee to Virginia and Maryland and California. Two slides from Texas on Celtis sp. fell into this group. However, these characters were also

found in various lots from the north: Ohio, New York, Illinois, Kansas, and Missouri. The third and fourth groups were represented by much fewer slides, 6 percent and 30 percent respectively. The third group had a cluster of one-barred microducts at the anterior spiracle and definite one-barred microducts forming transverse rows on abdominal segments I, II, and III, but lacking these ducts at the submedian macroducts. Distribution of this group included the eastern coast: Pennsylvania to Virginia and one each from Illinois and Missouri. The fourth group lacked almost all one-barred microducts; there were 0 to 6 present at each anterior spiracle and the transverse rows were absent. Specimens from Texas, Oklahoma, North and South Carolina, Mississippi, Alabama, Florida, and California formed this group. A few slides from Celtis were included in this group: Celtis occidentalis from Mississippi and Texas; Celtis sp. from Texas; Celtis laevigata from Florida; and Celtis reticulata from Texas. A fifth group, 2 percent, of specimens came from Celtis sp. exclusively, 3 slides from Texas and 1 from Louisiana; and were quite variable from the typical C. americana lacking the transverse rows of one-barred microducts; the group of one-barred microducts at the anterior spiracles was reduced to a few ducts, and the fourth submedian group of macroducts was usually absent. On two slides, however, a specimen from each had 1 and 2 submedian macroducts while in the other specimens from these same lots they were absent. In another lot the specimen was asymmetrical, one side with 2 macroducts and 1 microduct, the other side with only microducts. Ferris (1937) noticed this variation and in his material the submedian macroducts were replaced by two-barred microducts. The author did not observe two-barred microducts but 0 to 2 one-

barred microducts in this position.

Even though the range of variation was great the author tends to believe that all these specimens do belong as Chionaspis americana for the present. While most lots were easily placed in one of the five groups, there were slides present where specimens from the same lot needed to be placed in two different groups. Often one specimen had the transverse row and the other lacked it. Geographical subspeciation is probably occurring and subspecies could be distinguished based on transverse rows of dorsal one-barred microduct patterns.

MATERIAL STUDIED:

Description and ranges were taken from 1 specimen from each of the 23 following lots, on Ligustrum sp. and Prunus sp., St. Louis, Missouri (USNM); on Tilia glabra, New Haven, Connecticut (USNM); Moline elm, Richmond, Virginia (USNM); on Ulmus americana, Orange County, California (CDA); Bond County, Illinois (VPI&SU); Putnam County, Indiana (VPI&SU); New York City, New York (USNM); Champaign County, Ohio (VPI&SU); Monessen, Pennsylvania (USNM); Montgomery County, Virginia (VPI&SU); on Ulmus parvifolia, Stillwater, Oklahoma (VPI&SU); on Ulmus pumila, Stillwater, Oklahoma (OSU); on Ulmus sp., Birmingham, Alabama (USNM); Oak Hill, Florida (FDA); Fort Benning, Georgia (USNM); Topeka, Kansas (USNM); Elliot City, Maryland (VPI&SU); Stillwater, Oklahoma (VPI&SU); Providence, Rhode Island (USNM); Denison, Texas (USNM); Milwaukee, Wisconsin (USNM).

HOST AND DISTRIBUTION

Generally distributed throughout mid and eastern North America where Ulmus is present, occurring on the bark of trees. Slides on hand indicate its presence on Ulmus spp. in the following states:

Alabama, California, Connecticut, District of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, Wisconsin, and West Virginia.

Chionaspis americana Johnson

FIRST INSTAR NYMPH

Plate 2

DESCRIPTION

Body (fig. A) elliptical, widest at mesothorax tapering posteriorly, flattened ventrally, slightly convex dorsally. Live crawlers have black lateral eyespots anteriorly, a faintly segmented abdomen, colorless appendages and anal setae 3/4 length of body, color of live nymphs red, 7.5R/4/10, derm membranous. Mean body length of 10 specimens 258 (240-279) long and 142 (124-161) wide.

Pygidial margin (fig. B): Dorsally serrated. Ventrally with distinct lobes; median lobe acute, 5.56 (3.90-6.83) long; second trilobed, middle prominent, each rounded anteriorly; third usually single, nipple-like. Abdominal spines, pair long anal setae and tacklike setae present.

DORSAL SURFACE

Microducts (fig. C): Tubeshaped, 8.63 (7.81-10.2) long and 1.80 (1.46-1.95) wide, 2 submarginally on each thoracic segment.

Macroducts (fig. D): Tubeshaped, 11.0 (8.78-12.7) long and 3.66 (2.93-3.90) wide at top, narrowing to 2.10 (1.95-2.44) wide at duct orifice, 1 submedially anterior on cephalic area.

Setae: Long slender hairlike setae (fig. E) 9.37 (4.88-11.7) long, 4 submedially at cephalic region, 12 along margin at cephalothorax continuing marginally at thorax somewhat shorter 8.00 (6.83-10.7) long and 16 marginally on abdomen 5.37 (3.90-6.83) long. Short, tacklike setae (fig. F) 1.17 (0.98-1.95) long in a submedian longitudinal row on each body half.

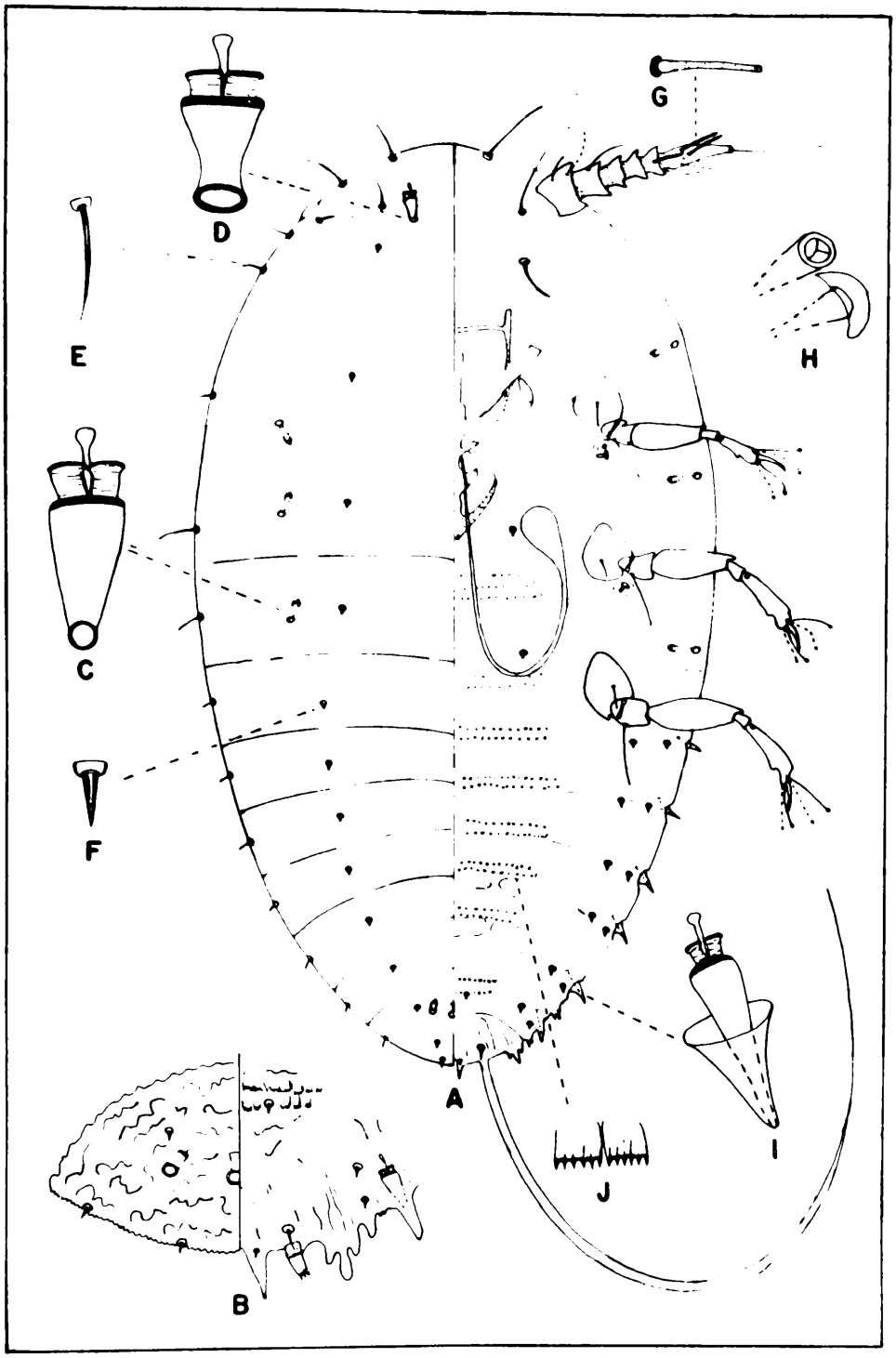

Plate 2.- Chionaspis americana Johnson, first instar

Anal area: Circular, anal orifice 2.25 (1.95-2.93) in diameter.

VENTRAL SURFACE

Eyes: Marginal, elongate ovoid, ca. 7.80 long and ca. 6.20 wide.

Antennae: Six-segmented, 53.5 (49.4-69.2) long. Distance between antennal bases 40.0 (32.1-44.5). Scape 9.75 (8.78-10.7) long and 11.0 (7.81-12.7) wide. Segments II to VI: 8.16 (6.83-10.8), 6.54 (4.88-7.81), 5.03 (4.88-5.86), 5.08 (3.90-5.86), 19.8 (17.6-23.4) long respectively. Each terminal segment with 1 long hairlike seta, 23.1 (20.5-28.3) long and 4 short fleshy sensory setae (fig. G) 12.7 (11.7-14.6) long. Setae on other segments: I, 2 hairlike setae, 14.5 (9.76-19.5) long; II, 1 hairlike seta; III, absent; IV, absent; V, 2 fleshy setae.

Clypeolabral shield: Length 50.9 (46.9-54.3); width 30.1 (24.7-32.1). Stylet loop 111 (96.3-138) long.

Labium: Ovoid, 25.2 (19.8-29.6) long and 29.7 (27.2-32.1) wide.

Legs: Three pairs, well developed, with 4 digitules on all legs. Small sensillum on bases of each trochanter and one sensilla located on proximal area of each tarsus.

Part of Leg	Lengths prothoracic	Lengths mesothoracic	Lengths metathoracic
Coxa	12.4(9.76-12.7)	13.4(11.7-14.6)	13.7(9.76-16.6)
Trochanter	8.10(6.83-9.76)	8.10(4.90-8.78)	8.58(5.87-10.7)
Trochanter seta	16.7(13.7-18.5)	19.0(16.6-22.4)	19.2(14.6-22.4)
Femur	22.1(18.5-24.4)	24.0(21.5-27.3)	24.3(21.5-26.4)
Tibia	6.54(5.86-7.81)	6.54(4.88-8.78)	5.86(4.88-7.81)
Tarsus	15.3(12.7-17.6)	16.8(14.6-19.5)	19.2(15.6-20.5)
Tarsal digitules	14.3(12.7-15.6)	14.2(12.7-15.6)	15.0(14.6-15.6)
Claw	9.37(7.81-10.7)	9.27(7.81-10.7)	9.37(7.81-10.7)
Claw digitules	11.3(9.76-12.7)	11.2(9.76-12.7)	11.4(9.70-13.7)
Entire leg	66.2(56.8-79.0)	71.7(64.2-88.9)	75.0(64.2-84.0)

Spiracles: Umbrella-shaped, anterior pair (fig. H) 6.34 (4.88-7.81) long, atrium 3.95 (3.90-4.39) wide with 1 associated trilocular pore 2.93 (1.95-3.90) in diameter; posterior pair similar in shape and size, without associated pores.

Abdominal spines (fig. I): Twelve stout marginal spines, 6.78 (4.39-11.7) long and 3.71 (2.93-4.88) wide at base each with an associated coneshaped one-barred microduct.

Microducts (fig. C): Coneshaped, 8.78 (6.83-9.76) long and 1.90 (1.46-1.95) wide, 6 submarginally on cephalothorax.

Macroducts: Absent.

Setae: Long slender setae (fig. E) 30.1 (24.4-35.1) long, 2 at margin and 4 submedially on cephalic region. Short tacklike setae (fig. F) 1.75 (0.98-1.95) long, 4 submedially on thorax and 6 pairs in longitudinal rows submarginally on each side of abdomen, 1 at base of each median lobe and 1 stout seta, 5.52 (2.93-6.83) long, laterad of each median lobe.

Minute spinelike structures (fig. J): Paired transverse rows medially on thorax and abdomen.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Celtis sp., 1(1), San Angelo, Texas, April 13, 1919, Coll. Hollinger, MSU, PAW088a, mounted at VPI&SU from dry material; on Ulmus americana, 1(5), Indianapolis, Indiana, CDA, no further data given; 1(3), Montgomery County, Virginia, May 8, 1969, Coll. A. D'Ascoli, VPI&SU, AD03c; the following collected at Montgomery County, Virginia by P. Willoughby: 1(3), April 10, 1972, PAW023a; 1(11), April 26, 1972;

PAW024a; 3(32), May 2, 1972, PAW029, 034, 035a; 1(2), June 13, 1972, PAW046c; on Ulmus sp., 1(14), Staten Island, New York, Coll. R. W. Roane, --, 1918, MSU, PAW089a, mounted at VPI&SU from dry material.

Chionaspis americana Johnson

SECOND INSTAR FEMALE

Plate 3

DESCRIPTION

Body (fig. A) ovoid, 414 (321-566) long and 240 (193-291) wide, broadest near middle tapering to a broad pygidium with well developed median lobes, black lateral eyespots visible anteriorly on live specimens, color light brown 5YR/6/8, derm membranous except for sclerotized pygidium. Cover composed of beigh first exuviae and secreted white wax.

Pygidial margin (fig. B): Broad almost subcircular with protruding lobes. Median lobes prominent, 14.5 (11.7-16.6) long, rounded at vertex, with 3 to 4 notches on sloping lateral margin, closely appressed, yoked together by tear drop shaped sclerosis. Second lobes reduced to 2 small notched lobules. Third lobes present as indistinct sclerotized area. Gland spines, stout needle-like setae, short tacklike setae, and macroducts present.

DORSAL SURFACE

Microducts: Absent.

Macroducts (fig. C): Two-barred marginal macroducts, 12.1 (9.76-14.6) long and 5.17 (2.93-6.83) wide at segments III to VII.

Setae: Six short tacklike setae (fig. D), ca. 0.98 long, in submedian longitudinal row on each side of cephalothorax to segment II; 8 longer setae at cephalic margin, 4.57 (3.90-6.83) long, continuing to somewhat shorter, 3.36 (2.44-3.90) long in a row on each margin of thorax and on abdominal segments I to IV. Stout needle-like setae, (fig. E), 10.7 (7.32-14.6) long, at margin of each lobe on segments V to VIII.

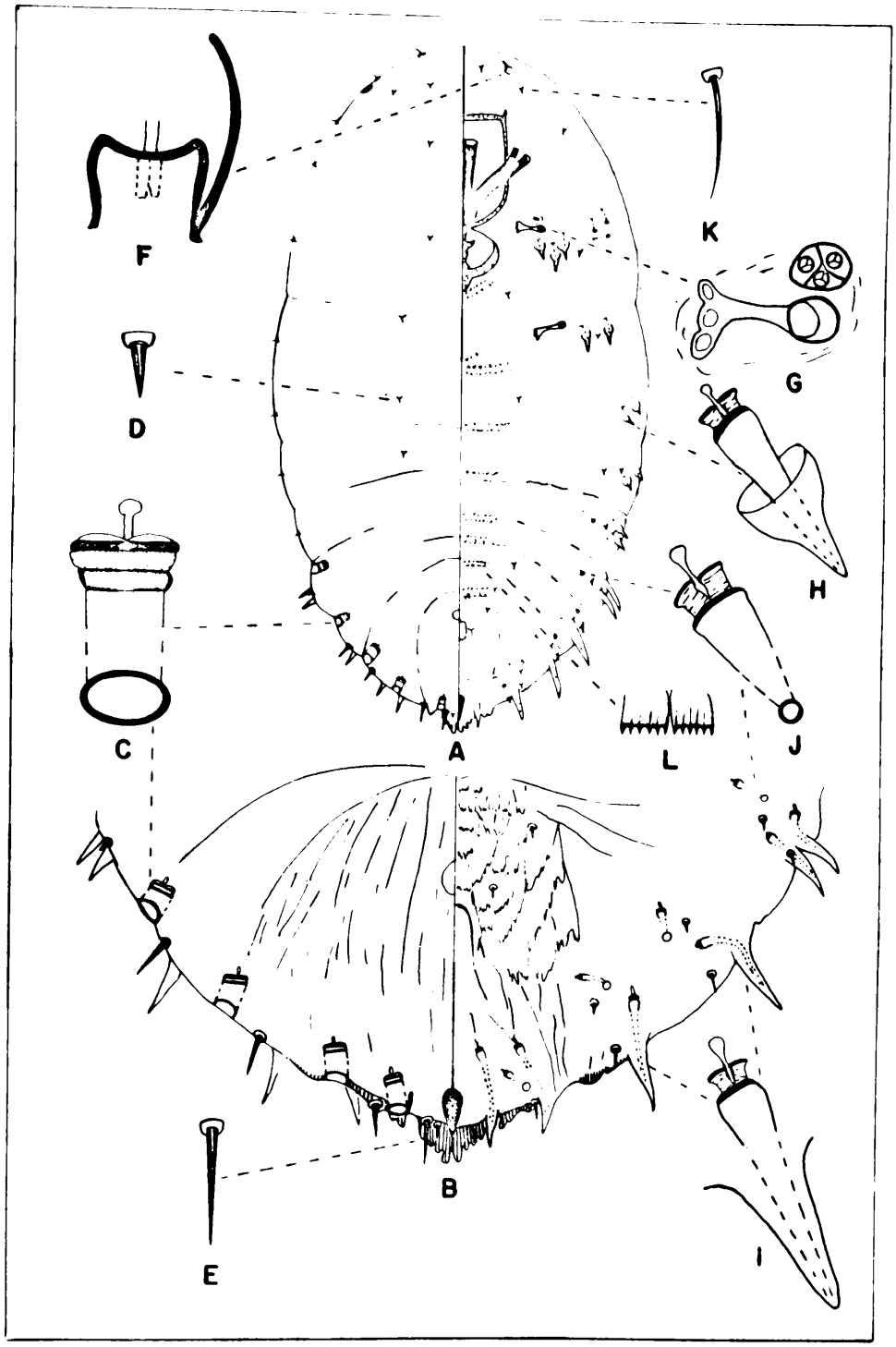

Plate 3.- Chionaspis americana Johnson, second instar female

Anal area: Sclerotized anal orifice elliptical, 6.44 (4.88-8.78) long and 7.17 (5.86-9.76) wide, located at 2/3 distance of length of pygidium from apex of median lobes.

VENTRAL SURFACE

Antennae (fig. F): Reduced to 1-segmented tubercles, 5.69 (4.88-7.81) long, and 5.64 (4.88-5.86) wide at base each with 1 lateral fleshy seta 10.3 (7.81-12.7) long, and 2 terminal setiform sensory setae ca. 3.58 long. Distance between antennal bases, 43.6 (30.3-53.7).

Clypeolabral shield: Length 77.6 (66.7-91.4); width 36.1 (29.6-46.9).

Labium: Ovoid, 29.6 (27.2-32.1) long and 35.1 (29.6-42.0) wide.

Legs: Absent.

Spiracles: Boneshaped, anterior spiracles (fig. G) 15.6 (13.7-16.6) long, atrium 4.83 (3.90-5.86) wide, each with 2 to 4 associated triloc-ular pores, 3.46 (2.93-3.90) in diameter; posterior spiracles similar in shape and size, without associated pores.

Gland tubercles (fig. H): Swollen proximally tapering distally to a spinelike projection, 12.1 (9.27-12.7) long and 3.51 (3.42-4.88) wide, proximally, with associated one-barred microducts, 2 or 3 posterior of each anterior spiracle, submarginal groups of 2 on both sides of thorax and segments I and II.

Gland spines (fig. I): Marginal, 17.2 (12.7-22.4) long, with asso-ciated one-barred microducts; 4 on segment III, 2 on each segment IV to VII.

Microducts: One-barred (fig. J), 9.17 (7.81-10.7) long and 1.80 (1.46-1.95) wide; submarginally 1 to 4 laterad of each anterior spiracle,

1 on each half of segments II to VI.

Macroducts: Absent.

Setae: Six to 10 slender needle-like setae (fig. K), 6.13 (2.93-12.7) long, scattered on cephalic area. Short tacklike setae (fig. D), 1.64 (1.46-1.95) long, in submarginal longitudinal row from anterior spiracles to segment VII, 2 submedially on each side of thorax, 8 in two submedian rows laterad of vulva, a marginal row on segments I to II becoming somewhat longer, 4.34 (2.93-5.37) long, on segments VI to VIII.

Minute spinelike structures (fig. L): In median transverse rows on thorax and abdomen.

Vulvar area: Reticulated in appearance with square shaped opening, about 9.27 (5.86-11.7) wide.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Ulmus americana, 1(2), Lawrence, Kansas, Feb. 28, 1899, Coll. S. J. Hunter, SEM, PAW075a; 1(2), same, March, 1934, Coll. L. R. Penner, SEM, PAW074a, both mounted at VPI&SU from dry material; following collected in Montgomery County, Virginia in 1972 by P. A. Willoughby: 1(9), May 26, PAW033a; 1(13), June 6, PAW045a; 1(4), June 13, PAW046a; 1(10), August 22, PAW098a; on U. crassifolia, 1(1), Comanche, Texas, May 12, 1918, Coll. Hollinger, MSU, PAW096a, mounted at VPI&SU from dry material; on U. parvifolia, 1(1), Lawrence, Kansas, Feb. 27, 1934, Coll. L. R. Penner, SEM, PAW068a, mounted at VPI&SU from dry material; on Ulmus sp., 1(1), no locality given, March 17, 1932, Coll. C. C. Hamilton, USNM, no number; no host given, 1(1), no data given, MSU, S4785.

Chionaspis americana Johnson

SECOND INSTAR MALE

Plate 4

DESCRIPTION

Body (fig. A) ovoid at molting becoming increasingly elongate-oval during development, 413 (331-509) long and 231 (203-252) wide at meso-thorax, black lateral eyespots visible on live specimens, color red 2.5YR/6/8, derm membranous. Cover composed of dorsal beige colored first exuviae and secreted white wax dorsally and ventrally late second instar.

Pygidial margin (fig. B): Subcircular, numerous lobules often distinguishable. Median lobes with toothlike notches at apex, square shaped, about 7.13 (5.86-7.81) long. Second lobes bilobed, inner lobule notched medially, lateral lobule nipple-shaped prominent. Third lobes trilobed, rounded posteriorly, often indistinct. Setae long and stout and short tacklike, with macroducts and one-barred microducts present.

DORSAL SURFACE

Microducts: Two types. One-barred microducts (fig. C), 7.56 (6.34-8.78) long, 3 or 4 in a transverse diagonal group on each side of pro-thorax; few submedially on thorax and first abdominal segments; 3 to 5 in each submedian longitudinal row on thorax and abdomen; 6 associated with indistinct marginal spines on mid-abdomen. Two-barred microducts (fig. D), 6.98 (5.86-9.76) long and 2.42 (1.95-2.93) wide, 2 to 5 in transverse rows each side of body on the meso- and metathorax and on abdomen.

Macroducts (fig. E): Two-barred, on margin of abdomen, 7.71 (5.86-9.76) long and 4.44 (3.90-5.86) wide, 4 on mid-abdomen, 6 at pygidial

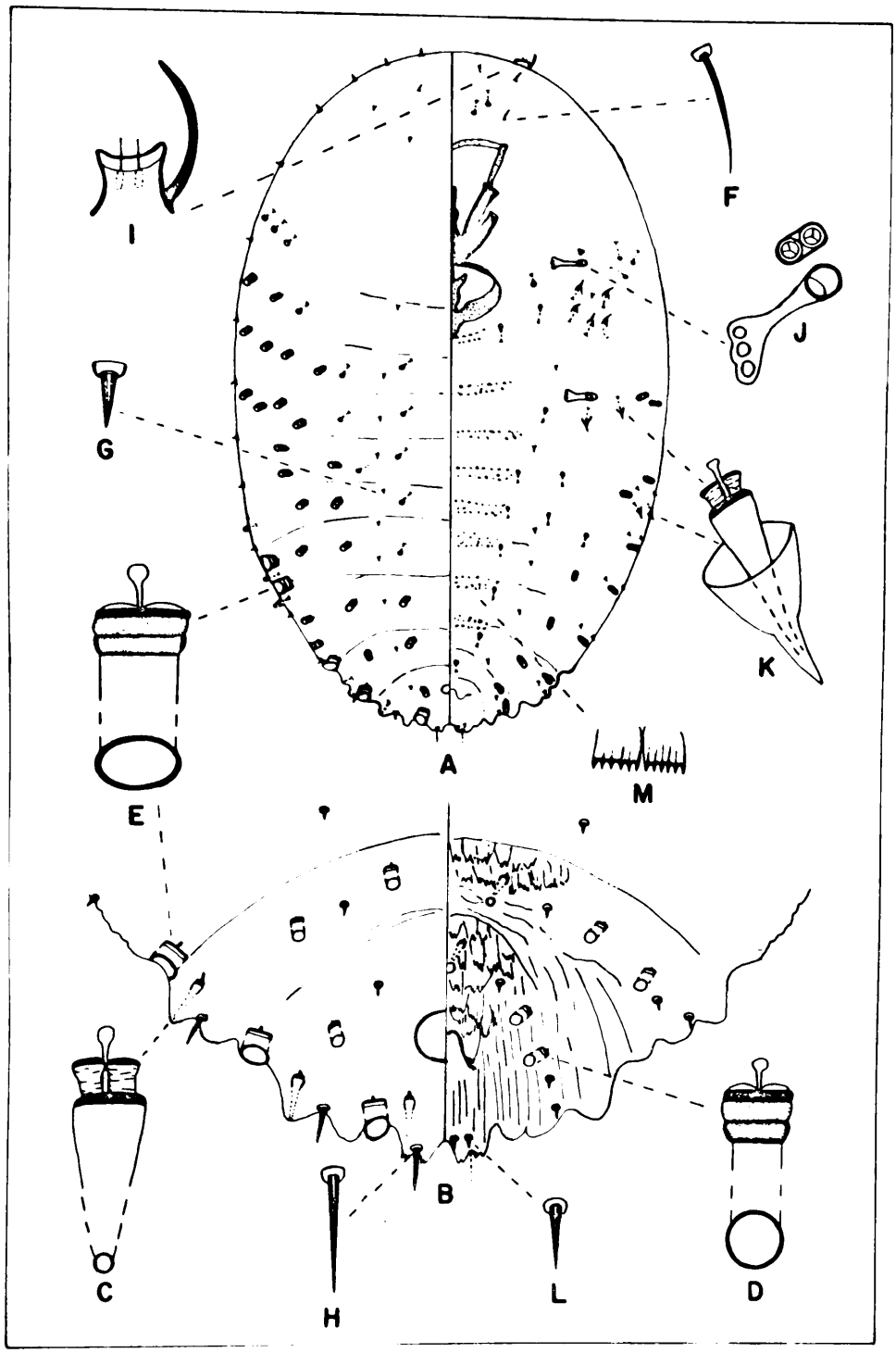

Plate 4.- Chionaspis americana Johnson, second instar male

lobes.

Setae: Few slender setae (fig. F), 5.19 (2.93-11.7) long, on cephalic region. Tacklike setae (fig. G), 1.37 (0.98-2.93) long in marginal rows extending from thorax to mid-abdomen, and in two submedian longitudinal rows from head to pygidium. Six stout setae (fig. H), 7.28 3.99-8.78) long, marginally at pygidial lobes.

Anal area: Large sclerotized anal orifice elliptical, 6.29 (4.88-7.81) long and 8.99 (7.81-10.7) wide, located about 1/3 the distance from apex of pygidium.

VENTRAL SURFACE

Antennae (fig. I): One-segmented tubercles, 6.25 (4.88-8.78) long and 5.81 (4.88-6.83) wide, each with 1 lateral fleshy seta, 8.58 (6.83-10.7) long, 2 short terminal sensory setae, about 1.27 (1.95-2.93) long. Distance between antennal bases 62.3 (45.9-88.8).

Clypeolabral shield: Length 75.1 (71.6-81.5); width 33.1 (24.7-37.1).

Labium: Elliptical 30.6 (24.7-39.5) long, and 34.1 (27.2-39.5) wide.

Legs: Absent.

Spiracles: Clubshaped, anterior spiracles (fig. J), 16.8 (13.2-19.5) long and 4.64 (3.90-5.37) wide at atrium, with 1 to 3 associated trilocular pores, 3.18 (2.93-3.42) in diameter; posterior spiracles similar in shape and size, but without associated pores.

Gland tubercles (fig. K): Broad basally one-half their length and narrowing to apex, 10.7 (6.83-13.7) long and 3.76 (2.93-4.39) wide with projecting one-barred microducts, submarginally in 3 groups on each body half: 3 to 5 caudad of each anterior spiracle, 2 at each posterior

spiracle and 2 to 4 on segment II.

Gland spines: Absent.

Microducts: One-barred microducts (fig. C), 7.08 (4.88-8.78) long and 1.58 (0.98-1.95) wide; submedially, 4 present at apex of clypeolabral shield, groups of 2 or 3 ducts laterad and mesad each anterior spiracle; and a submedial row on each side extending the length of abdomen. Two-barred microducts (fig. D), 6.83 (5.37-8.78) long and 2.69 (1.95-2.93) wide, in 2 abdominal longitudinal rows on both sides of body: Marginal rows beginning from posterior spiracle, and submarginal rows from mid-abdomen.

Macroducts: Absent.

Setae: Six slender hairlike setae (fig. F), 7.47 (5.86-9.76) long, anterior of clypeolabral shield. Short tacklike setae (fig. G), 1.61 (0.98-2.44) long, 2 or 3 submedially on each side of thorax, 4 in a longitudinal submedian row on each side from segment III to VI, and paired rows marginally and submarginally on abdomen. Short stout setae (fig. L), 3.76 (2.93-4.88) marginally at pygidial lobes.

Minute spinelike structures (fig. M): In median transverse rows on thorax and abdomen.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Ulmus americana, the following collected in Montgomery County, Virginia by P. A. Willoughby in 1972: 2(5), May 26, PAW 033a,b; 1(3), June 6, PAW041c; 1(12), June 6, PAW045a; 1(2), June 13, PAW046c; 1(3), June 13, PAW048a; 1(6), Aug. 22, PAW099a; 1(3), Aug. 28, PAW076a; 2(2), Sept. 5, PAW077a,b; on Ulmus sp., 1(1), Spalding County,

Georgia, Aug. 28, 1968, Coll. H. H. Tippins, UGAES, HHT-261-68; 1(1), Staten Island, New York, - -, 1918, Coll. R. W. Roane, MSU, PAW89a, mounted at VPI&SU from dry material.

Chionaspis americana Johnson

MALE PREPUPA

Plate 5

DESCRIPTION

Body (fig. A) spindle-shaped, rounded anteriorly, and narrowing p posteriorly to a sharply, pointed apex; live specimens with black lateral eyespots, color yellow brown 7.5YR/6/8. Enclosed within a white cocoon of secreted wax with terminal dorsal first exuviae. Measurements of 10 mounted specimens, 606 (521-679) long and 221 (185-272) wide at mesothorax.

Body setae: Dorsally, 4 dorsal head setae (dhs) (fig. B) hairlike, 3.58 (1.95-8.58) long, 2 at anterior margin of head, 2 at base of each antenna, 1 submedially laterad of each eyespot. Other body setae tacklike, (fig. C). Six thorax dorsal setae (tds) ca. 0.98 long submedially on mesothorax and metathorax, 6 marginally on cephalothorax. Seven abdominal dorsal setae (ads), 1.80 (0.98-2.93) long, in each of the two longitudinal rows located submedially on abdomen. About 8 abdominal pleural setae (aps) (fig. D), 4.27 (1.95-5.86) long, submarginally and marginally in a longitudinal row on each half of abdomen. Ventral tacklike setae (fig. C), few. Several ventral head setae (vhs) 3.06 (1.46-4.88) long. Eight abdominal ventral setae (avs), 2.00 (0.98-2.93) long, submedially, 1 on each segment IV to VII. Minute spinelike structures (fig. E) in transverse longitudinal rows on thorax and abdomen.

Head: Not clearly separated from prothorax, tapering toward apex without any ridges.

Antennae: Elongate, parallel-sided, rounded at apex, incompletely

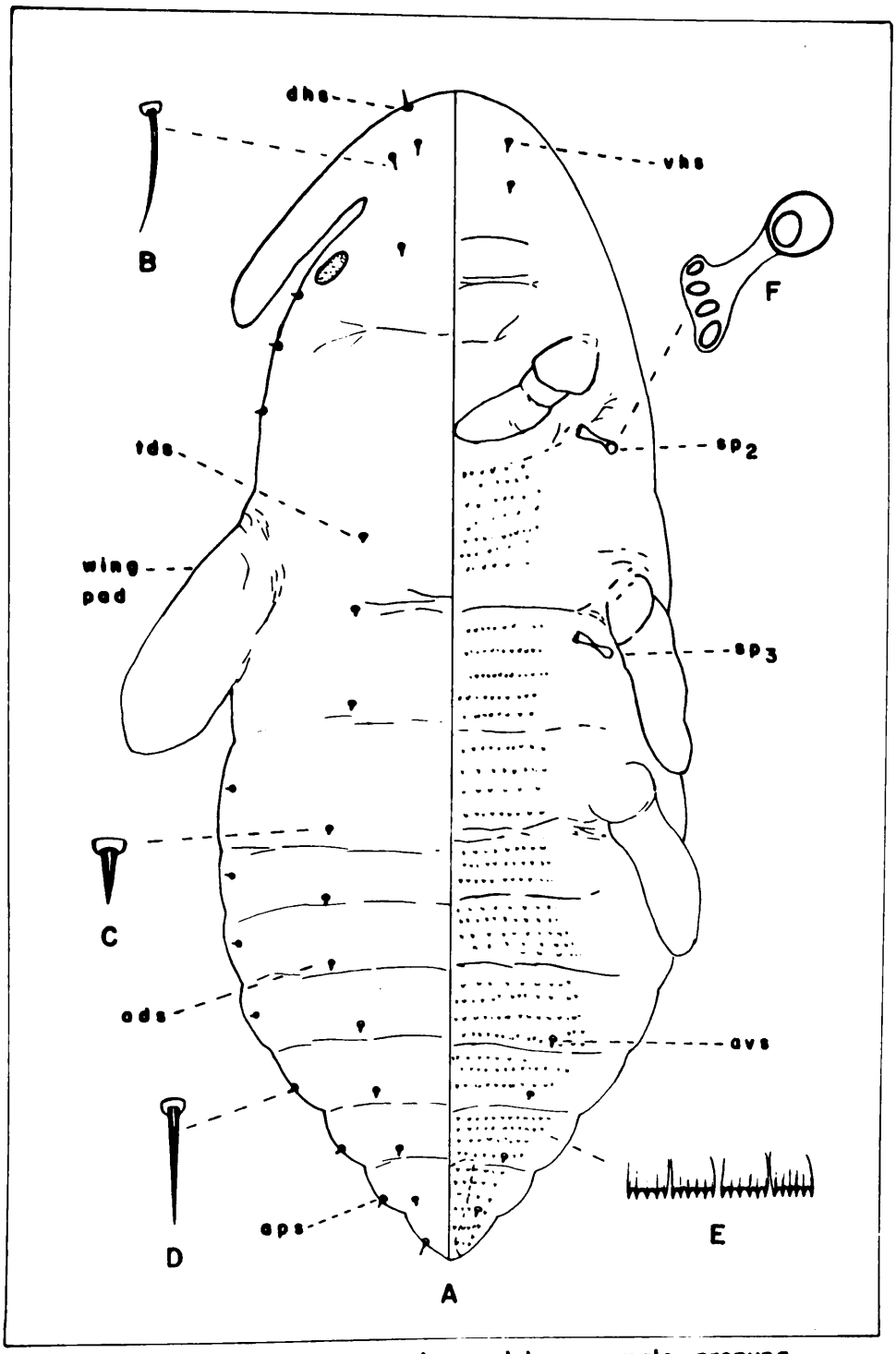

Plate 5.- Chionaspis americana Johnson, male prepupa

segmented, 133 (104-170) long and 29.9 (24.7-34.6) wide, without setae. Distance between antennal bases 97.5 (74.1-111).

Thorax: Not clearly separable from head or abdomen, about 221 (183-259) long and 215 (161-247) wide at mesothorax.

Wing pads: Occasionally present, budlike, 106 (86.5-121) long and 51.9 (37.1-66.7) wide.

Spiracles (fig. F): Submarginally on thorax; anterior 23.2 (19.8-27.2) long, posterior usually smaller, 21.7 (18.5-24.7) long, each atrium, 7.60 (7.41-9.88) wide, without associated pores.

Legs: Poorly developed, only coxa readily discernable, without setae. Length and width at base from prothoracic to metathoracic: 87.9 (61.7-111) long, and 31.4 (24.7-37.1) wide; 92.9 (76.6-111) long and 37.8 (29.6-49.4) wide; and 90.7 (74.1-114) long and 36.1 (29.6-42.0) wide.

Abdomen: Eight segments are faintly distinguishable, about 237 (198-296) long and 238 (183-301) wide. With a tubelike structure tapering posteriorly inside the last two abdominal segments, probably enclosing the developing aedeagus.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots collected at VPI&SU in Montgomery County, Virginia by P. A. Willoughby in 1972, on Ulmus americana, 1(2), June 6, H22f; 3(9), June 13, H23a,b,e; 3(10), Aug. 28, H34b,d,e; 2(3), Sept. 5, H35b,e; 1(1), Sept. 19, H37d.

Chionaspis americana Johnson

MALE PUPA

Plate 6

DESCRIPTION

Body (fig. A) spindle-shaped, rounded anteriorly with long antennal sacs compressed laterally along body margin, tapering gradually posteriorly into a strongly projecting tubular genital segment. Live specimens red 2.5YR/5/10, completely enclosed within secreted white wax test with their terminal first exuviae serving as attachment point to plant material. Size of 10 mounted specimens 681 (595-798) long and 200 (158-268) wide at mesothorax.

Body setae: Small tacklike (fig. B) in a regular pattern on dorsum. Eight dorsal head setae (dhs), 3.51 (1.95-4.88) long, 2 at anterior margin, 2 medially at each antennal base, 1 posteriorly at each eye. About 12 dorsal thoracic setae (tds) about 1.14 (0.98-1.95) long, 8 marginally at cephalothorax, 4 submedially on posterior region of thorax. Sixteen abdominal dorsal setae (ads), 2.83 (1.46-2.93) long, in two longitudinal submedian rows on abdomen. Sixteen abdominal pleural setae (aps), (fig. C), 4.10 (3.90-5.86) long, in a longitudinal row on each side of the body, submarginally at anterior of abdomen and becoming marginal at posterior of abdomen. Two setae on genital segment (gts), 2.81 (1.95-3.90) long, located submedially at base. A few tacklike setae on ventrum.

Six ventral head setae (vhs), 3.25 (1.95-4.88) long, submedially at anterior area of head. No setae on thorax. Four abdominal ventral setae (avs), 2.64 (1.95-3.90) long, in a longitudinal row submedially on each body half from segments IV to VII. Minute spinelike structures

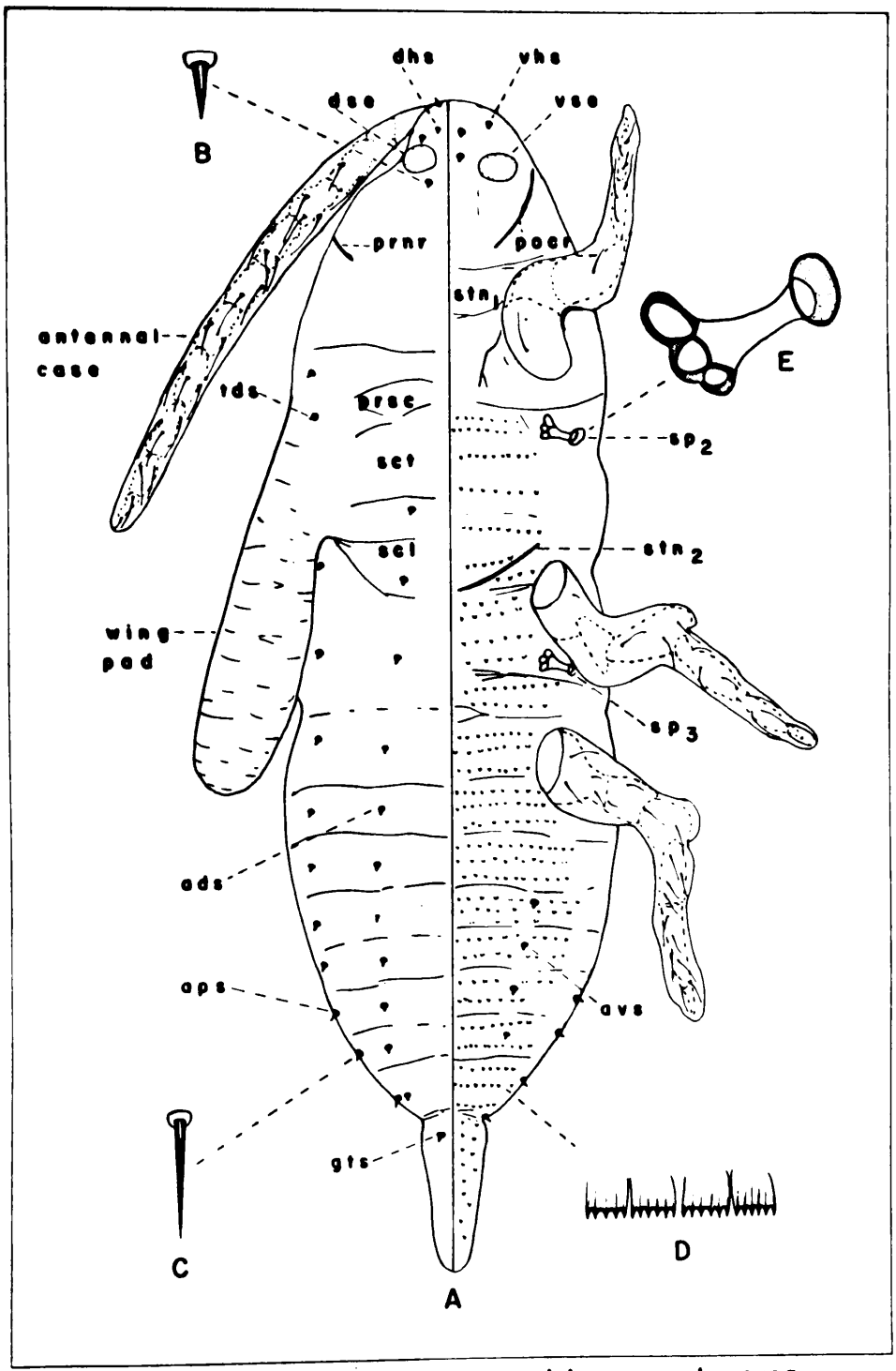

Plate 6.- Chionaspis americana Johnson, male pupa

(fig. D) in transverse longitudinal rows on thorax and abdomen.

Head: Indistinctly differentiated from thorax and rounded apically. Postocular ridge (pocr) and pronotal ridge (prnr) weakly sclerotized.

Eyes: Dorsal simple eyes (dse) indistinct, in most, about 22.99 (17.3-32.1) long and 17.6 (9.88-24.7) wide and separated by about 68.0 (22.2-104); ventral simple eyes (vse) distinct in specimens mounted in Hoyer's 26.7 (19.7-34.6) in diameter, separated by 12.0 (2.47-32.1).

Antennae: Antennal case, 265 (222-333) long and 26.2 (19.8-34.6) wide at base tapering apically, enclosing partly developed antennae, each antenna with ten segments well developed and with antennal setae visible through sac. Distance between antennal bases 71.9 (54.3-86.5).

Thorax: Broadly fused at head and at abdomen, about 213 (161-299) long from apex prosternum (stn_1) to first abdominal segment, 200 (158-268) wide at mesothorax.

Wing pads: Elongate paddle-like, present or absent, 168 (128-252) long and 68.4 (54.3-84.0) wide, without setae.

Spiracles (fig. E): Ventral, 2 pairs submarginal on thorax, anterior 23.3 (19.8-27.2) long, posterior slightly smaller 21.7 (17.3-24.7) long, and atrium 8.96 (7.41-12.4) wide, both pairs without associated pores.

Prothorax: Dorsally without recognizable structures. Ventrally, prosternum (stn_1) faintly visible on specimens mounted in Hoyer's. Pores undetected.

Mesothorax: No recognizable structures or pores visible.

Legs: With saclike structures enclosing developing legs; coxa, trochanter, femur, tibia, tarsus and claw visible with associated setae.

Lengths and widths at base of pupal leg sacs prothoracic to metathoracic: 189 (151-222) long and 44.2 (32.1-56.8) wide; 203 (173-239) long and 44.0 (39.5-49.4) wide; and 216 (175-277) long and 45.5 (37.1-54.3) wide. Prothoracic legs extended anteriorly often folded across head, mesothoracic and metathoracic legs extending posteriorly laterad of the body.

Abdomen: Fused broadly with thorax narrowing gradually posteriorly and terminating in sharply projecting genital segment, about 241 (178-272) long and 221 (173-235) wide at base, not including genital segment. No pores detected.

Genital segment: Tubular, broad at base tapering to rounded apex, 108 (93.9-119) long and 47.7 (34.6-56.8) wide at base.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Ulmus americana, 1(1), Lawrence, Kansas, Feb. 28, 1899, Coll. S. J. Hunter, SEM, PAW075b, mounted at VPI&SU from dry material; the following collected in Montgomery County, Virginia by P. A. Willoughby in 1972: 1(7), June 13, H23e; 1(4), June 20, H24d; 2(8), Aug. 28, H34b,e; 2(17), Sept. 5, H35b,d; 2(10), Sept. 12, H36a,e; 1(5), Sept. 19, H37a.

Chionaspis americana Johnson

ADULT MALE

Plate 7

DESCRIPTION

Small spindle-shaped body terminating in a long thin sharp stylus, (fig. A) with large black eyespots defining the head on live specimens, long slender appendages, hairy antennae, and three pairs of well developed slender legs with bushy appearance due to many long setae. Males dimorphic; some with a fully developed pair of membranous wings, others appearing wingless. Color dark red 2.5YR/4/8, derm membranous except for sclerotized areas on head and thorax. Male test tricarinate, about 6 mm long and 2 mm wide, composed of secreted white wax, and light beige first exuviae about 3 mm long and 2 mm wide. Measurements of 8 winged specimens mounted in Hoyer's, 874 (817-941) long and 224 (198-254) wide at mesothorax; 7 brachypterous specimens measured were smaller, 747 (639-817) long and 165 (161-167) wide at mesothorax.

Body setae: Numerous, generally confined to head and abdomen. Dorsally: Dorsal head setae (dhs) very long and stout with well developed bases, 16.4 (9.76-24.4) long, a pair at apex of midcranial ridge (mcr) and 3 on each dorsal lateral branch of midcranial ridge (lmcr) forming an inverted "Y" pattern, 2 submedially on postoccipital ridge (por), 2 genal setae (gs), 9.10 (5.86-12.7) long, submarginally on each gena; tacklike setae, 6.29 (3.42-8.78) long, about 6 submarginally on prothorax, 2 submarginally on each membranous tegula (teg), 2 submedially on scutellum (scl), and 2 submedially on metathorax; abdominal dorsal setae (ads) tacklike on segments I to VII, 7.62 (4.88-12.7) long,

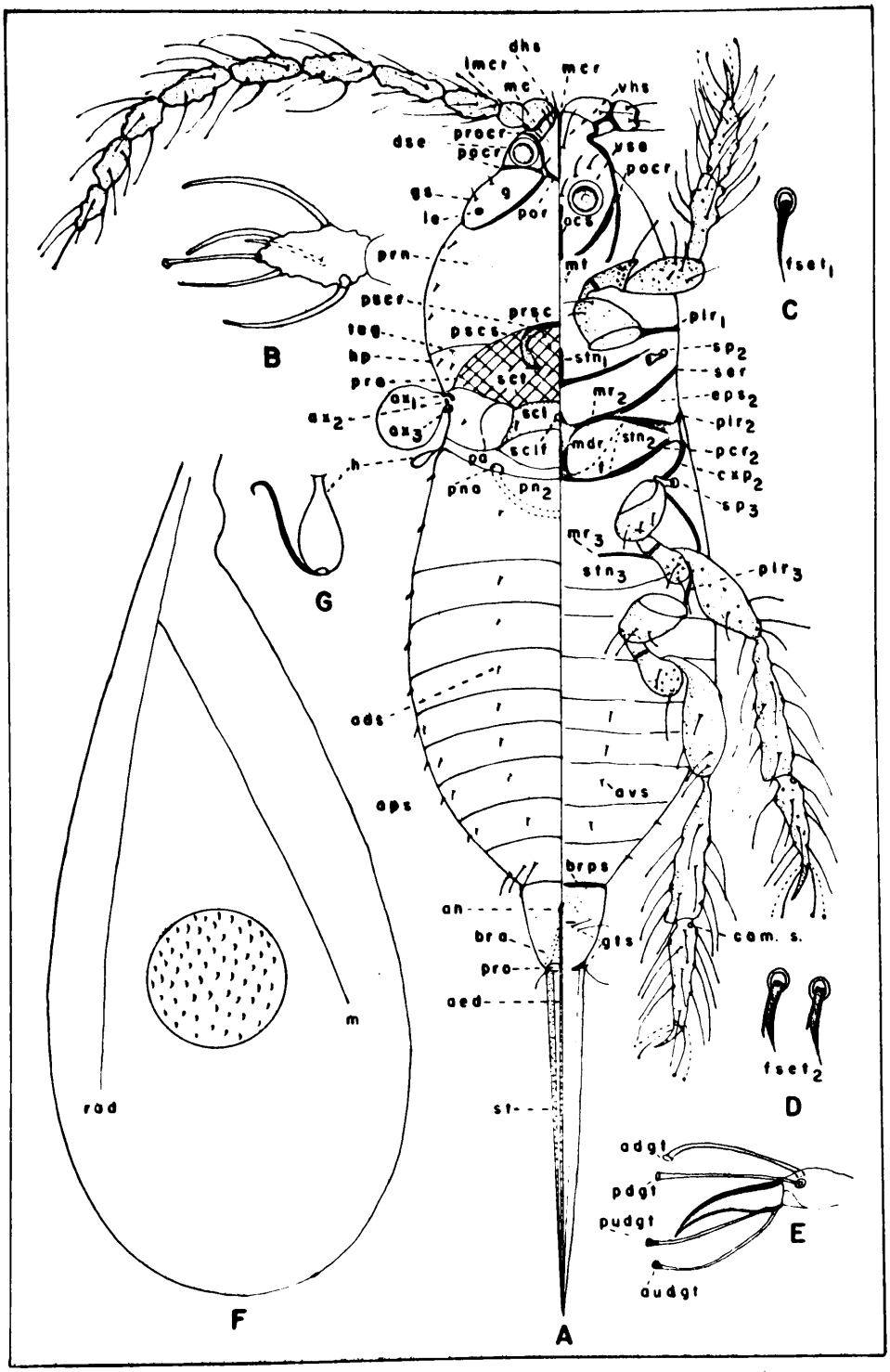

Plate 7.- Chionaspis americana Johnson, adult male

and long hairlike on segment VIII, 15.7 (11.7-17.6) long, in 3 longitudinal rows on each side of body, about 8 marginally on segments I to VII, 4 or 5 submarginally IV or V to VIII and 8 submedially I to VII; genital setae (gts) long hairlike, 19.9 (11.7-26.4) long, 2 marginally at base of style (st). Ventrally: Ventral head setae (vhs) long and stout, 25.8 (20.5-33.2) long, a pair subapically at midcranial ridge (mcr), 3 or 4 in a row on each side of head extending from next to ventral simple eye (vse) obliquely to above eye; none detected on thorax; abdominal ventral setae (avs) tacklike, 6.72 (3.90-9.76), 8 in two longitudinal submedian rows on segments IV to VII; genital setae (gts) hairlike, 29.6 (22.4-34.2) long, 4 submarginally and 2 marginally at base of style (st).

Head: Indistinctly separated from thorax, short, eggshaped broadening posteriorly into thorax with distinct sclerotized ridges, two pair of eyespots, long setae, and a pair of 9- or 10-segmented antennae present, 55.0 (49.4-59.3) long from apex to postoccipital ridge (por) and 116 (98.8-133) wide across gena. Dorsally, median crest (mc) distinctly diamond-shaped, bounded by heavily sclerotized well developed midcranial ridge (mcr), dorsal lateral branches (lmcr) and postocciptial ridge. Gena (g) lateral, separated anteriorly by postocular ridge (pocr), and medially by oblique gular suture. Ventrally, head more distinctly elongate and defined by well developed ridges; midcranial ridge (mcr) extending medially from anterior of ventral simple eyes (vse) to the ventral apex of head between antennae to dorsal surface where it branches into lateral dorsal arms (lmcr). In most specimens a distinct sclerotized ocular sclerite (ocs) is present medially from opposite the

ventral simples eyes to posterior of head region. Postocular ridge (pocr) well developed, laterally supporting head.

Antennae: Long slender, usually 10-segmented, 328 (352-402) long, but occasionally 9-segmented 333(297-365) long, due to apparent fusion of two adjacent segments, antennal bases separated by 22.9 (14.8-27.2). Scape, roughly quadrate, widest segment, supported ventrally by well developed inverted "Y-shaped" basal ridge; pedicel, short and broad; segments III to VIII or IX, cylindrical, wider medially than at ends, each nearly subequal to the others; terminal segment (fig. B) a rough cone-shape, shorter than preceding. Setae: two or 3 short slender setae ca. 17.2 long on segment II; equal distribution of 4 to 15 long fleshy setae per segment on flagellum which gives antennae bushy appearance, 45.5 (37.1-50.7) long; terminal seta on IX or X, 32.5 (24.4-38.8) knobbed at tip, occasionally 1 or 2 fleshy setae on terminal segment also knobbed. Average lengths and widths at broadest area of antennal segments are as follows (9-segmented, 5 specimens measured; 10-segmented, 6 specimens measured):

	I	II	III	IV	V	VI	VII	VIII	IX	X
Lengths:	21.2	19.3	48.4	47.4	44.5	52.1	20.0	43.0	36.8	
Widths:	28.4	22.2	21.5	14.1	16.8	16.0	17.8	20.3	15.1	
Lengths:	25.3	18.1	51.4	50.4	48.2	37.1	39.5	37.1	37.1	37.1
Widths:	26.8	21.6	14.2	13.2	13.8	15.0	14.4	14.6	17.3	14.3

Spiracles: Submarginal, one pair each on meso- (sp_2) and metathorax (sp_3), 21.6 (19.8-24.4) long; atrium 9.73 (7.41-10.7) wide.

Legs: Three pair well developed long slender legs, with numerous associated setae conspicuous on femur, tibia and tarsus, giving legs

bushy appearance. Ratio legs to entire body length 1:2.5. Coxa (cx): conical, broad basely narrowing apically with 3 to 5 short hairlike setae, 21.2 (19.5-26.4) long, on distal half. Trochanter (tr): slender, narrow at coxal insertion flaring to rounded apex, a chair of diamond-shaped sensilla encircling trochanter proximally; trochanter teeth on ventro-distal surface often more distinct on foreleg than on others. Setae, hairlike, 1 to 3 on each leg, 1 seta very long, 24.0 (15.6-29.3), remaining setae much shorter. Femur (fm): robust, elongate bulging ventro-laterally, femur teeth present ventrally without a regular pattern. Setae, hairlike, 1 to 7 on each foreleg, 2 to 7 on midleg and 4 to 8 on hindleg, 18.1 (11.7-24.4) long. Tibia (tib): longest leg segment, slender, knobby in appearance due to prominent setal bases, tibial teeth scattered ventrally. Setae fleshy, usually present on distal 2/3 of segment, 7 to 9 on each foreleg, 9 to 13 on midleg, and 9 to 15 on hindleg, each 20.4 (14.6-22.4) long. Tarsi (tar): cylindrical, wider proximally narrowing to slender distal end, a campaniform sensilla (cam. s.) on basal margin, and tarsal teeth present. Setae, evenly distributed on tarsi, fleshy ($fset_1$) (fig. C) and bifurcated ($fset_2$) (fig. D), 8 to 16 on foretarsus, 10 to 17 on midtarsus, and 14 to 22 on hindtarsus, each 20.3 (17.6-25.4) long. Tarsal digitules (adgt, pdgt) (fig. E) well developed with distinct knob, always longer than claw and nearly same lengths on all legs, 23.4 (21.5-25.4) long. Claws (fig. E): long, slender, wide basally narrowing to sharp apex, slightly curved. Ungual digitules (audgt, pudgt) well developed with small knob, always longer than claw and same lengths on all legs, 19.7 (16.6-21.5) long.

Part of Leg	Lengths Prothoracic	Lengths Mesothoracic	Lengths Metathoracic
Coxa	47.8(37.1-51.9)	53.0(42.0-61.8)	51.9(44.5-56.8)
Trochanter	50.2(49.4-56.8)	50.4(46.9-55.6)	53.0(49.4-65.8)
Femur	72.2(64.2-79.0)	74.9(66.7-84.0)	82.6(74.1-96.3)
Tibia	62.6(54.3-74.1)	79.3(74.1-86.5)	79.5(66.7-93.9)
Tarsus	49.9(46.9-56.8)	60.7(51.9-66.7)	65.1(56.8-69.2)
Claw	20.1(17.3-24.7)	19.6(17.3-22.2)	18.8(17.3-22.2)
Entire leg	270(248-303)	296(272-324)	312(297-328)

Eyes: Two pairs of eyes prominent. Dorsal simple eyes (dse) at lateral margin, round, 14.9(12.4-17.3) in diameter, separated by about 26.1. Preocular (procr) and postocular (pocr) ridges supporting eye. Ventral simples eyes (vse) submedial, round, 15.2 (12.4-18.6) in diameter, separated by ca. 21.0, larger than dorsal simple eyes and located more posteriorly. Spotlike ocellus (le) weakly sclerotized, posterio-laterally on gena (g).

Thorax: Indistinctly divided from head and from abdomen, 255 (240-296) long from postoccipital ridge to first abdominal segment and 165 (161-167) wide across mesothorax. Prothorax: Membranous with few heavily sclerotized structures. Dorsally, pronotal ridge (prn) submarginal, sometimes discernable as slightly sclerotized small sclerite. Ventrally, fairly long, propleural ridge (plr_1) distinct, located transversely at coxal base; prosternum (stn_1) prominent medially with indistinct sclerite at base and with lateral arm extending transversely. Mesothorax: Heavily sclerotized dorsally and moderately sclerotized ventrally. Dorsally, prescutum (prsc) circular bounded by heavily sclerotized prescutal ridge

(pscr) and lightly sclerotized prescutal suture (pscs). Prealare (pra) "Y-shaped", extending from apex of prescutum (prsc) transversely forking submedially and the two arms enclosing the membranous humeral plate (hp). Humeral plate (hp) membranous with distinct small tegula (teg) present. Scutum (sct) reticulated, crescent-shaped, about 46.6 (32.1-69.2) long, cradling prescutum (prsc). Scutellum (scl) oblong, 14.4 (12.4-17.3) long and 59.5 (51.9-64.2) wide on brachypterous males and larger on pterygotous males, 23.6 (14.6-29.6) long and 79.5 (71.6-96.3) wide, anteriorly heavily sclerotized and posteriorly with small elliptical membranous foramen (sclf). Posterior mesothorax with well developed postalare (pa) laterally joining wing articulation formed by three small sclerites; first, second and third axillary (ax_1, ax_2, and ax_3). Ventrally, mesosternum (stn_2) elliptical, 26.8 (19.8-32.1) long and 77.6 (69.2-86.5) wide in brachypterous condition, and 84.3 (56.8-141) long and 115 (71.6-141) on winged specimens, enclosed by heavily sclerotized ridges; medial ridge (mdr) joining anteriorly with transverse marginal ridge (mr_2) and posteriorly with transverse precoxal ridge (pcr_2). Mesofurca (f) distinct, projecting as "U-shaped" structure under mesosternum. Mesoepisternum (eps_2) triangular, membranous area anterolaterally branching posteriorly to join coxal process (cxp_2), and dorsally to articulate with postalare (pa). Metathorax: Largely membranous, dorsally with small sclerotized pleural wing process supporting halters; without any other visible structures. Ventrally, metasternum (stn_3) present as weakly sclerotized area, pleural ridge (plr_3) present longitudinally.

Wings: Two types present, majority brachypterous (fig. A), oval,

39.3 (27.2-49.4) long and 28.0 (19.8-34.6) wide without veins, surface covered with many microtrichia; few pterous (fig. F), 573 (482-705) long and 219 (192-260) wide with typical venation, radial vein anteriorly branching distally into median vein; surface coated with microtrichia.

Halters: Two conditions present, majority brachypterous with small paddlelike halters, 22.1 (9.88-29.6) long, without an apical seta; all pterygotes with fully developed typical halters as a narrow stem widening distally, (fig. G), 40.5 (32.1-44.5) long, bearing an apical seta recurved at tip, nearly subequal to halter, 41.4 (39.5-44.5) long; a few brachypterous males exhibit this latter condition.

Abdomen: Broadly joined at the thorax gradually narrowing posteriorly to genital segment, 221 (183-257) long not including genital segment and 186 (168-200) wide at segment I, 8-segmented, entirely membranous dorsally and ventrally except for slight sclerotized segmentation lines.

Genital segment: Bulbous, entire segment 242 (210-266) long, basal section 43.7 (39.5-49.5) long and 51.8 (46.9-61.9) wide at base, narrowing distally to long thin style (st), 197 (185-209) long. Dorsally, anus (an) circular, located near apex and aedeagus (aed), long and thin, with its dorsal lip near anus (an) and extending to end of style. Internally, basal rod (bra) posteriorly and penial sheath (pro) well developed. Ventrally, basal ridge of penial sheath (brps) separating genital segment from abdomen.

MATERIAL STUDIED

Description and measurements were taken from each of the following lots (VPI&SU) collected in Montgomery County, Virginia in 1972 by P. A.

Willoughby on Ulmus americana, 1(4), June 20, PAW050a; 1(5), June 26, PAW038b; 1(6), July 3, PAW039a; 3(17), Aug. 18, PAW037a,b,c; 1(1), Aug. 28, H34e; 2(14), Sept. 5, H35b,e; 1(2), Sept. 5, PAW077c; 2(6), Sept. 12, H36a,d; 2(6), Sept. 19, H37a,d; 1(1), Sept. 26, PAW078a.

D. BIOLOGICAL NOTES ON CHIONASPIS KOSZTARABI

Species is bivoltine in Montgomery County, Virginia, overwintering as mature fertilized females in 1972. Eggs were deposited in the spring and were present through the last week of June. There were two colors of eggs observed, most were pale orange 2.5YR/7/8, others were light yellow 5Y/8/6, and occasionally both colors were found under a single female. The eggs were elliptical, about 2 mm long and 1 mm wide, with black lateral eyespots visible through the chorion. In embryos mounted in Hoyer's the antennae and appendages were easily distinguishable extending submedially toward the anal end on the ventral surface. Counts of eggs that had been deposited by 10 live females on May 20, 1973 included 56 (35-82) per female. There was no evidence that hatching had begun and females still obviously contained undeposited eggs.

Crawlers were first present about June 2, 1972 continuing through the first week of July. On June 2, an egg-filled live female, deposited eggs; empty egg shells, crawlers and settled crawlers were observed under a single test. Crawlers were found on branches, twigs and leaves. In 1973 crawler emergence began about May 28 with crawlers and a few unhatched eggs still present on June 12.

Second instar males and females were found from June 14 to July 14 in 1972. Females enlarged their covers in length and width; those on the leaves secreted an obvious ventral cover which was not observed in specimens from twigs. Males secreted wax both dorsally and ventrally enlarging tests only lengthwise. Males gradually darkened from lemon yellow color to orange as development progressed through the pupal

stages. Second instar females and males can be distinguished from each other as live specimens under low power magnification by several characters: shape of females is oval to pearlike, while males are elongate-oval; females are bright yellow at the head and thorax and deep gold at the pygidium, males are uniformly yellow; and females have an acute pygidium with faint lobes, males have a rounded pygidium without obvious lobes. In both sexes the live specimens have distinct black lateral eyespots. Both were also found on leaves crowded at the midrib pubescence and in cracks and crevices of twigs. Males seemed equally distributed between leaves and twigs while females were more numerous on the twigs.

Second instar males completed their development when the test was completed extending beyond the pygidium with slits opening laterally for male emergence. Male prepupae were first observed on July 7, 1972 and pupal males July 14, 1972. Black eyespots were visible on live specimens.

Adult males emerged from July 10 through July 21 living only a few hours. Males of this generation were dimorphic with winged and nonwinged forms collected.

The first adult females were present July 7, 1972. Young females were lemon yellow in color becoming orange as their eggs developed. The first eggs of the second generation were observed July 20, 1972 with about 20 to 30 eggs laid by each female before hatching began. Some eggs were still present by September 28, 1972. Crawlers were observed from August 10 to the end of September in 1972, settling on both twigs and leaves. Again females were more numerous on the twigs but were

found regularly on the leaves. Fraxinus americana leaves began to drop on October 12, 1972 and nearly all leaves were lost by October 26 in Blacksburg, Virginia and therefore leaf infesting females were presumably lost to the next generation. Adult females of the second generation were first present on September 14 in 1972. Males emerged from September 21 through the end of October. Of the total of 98 pupae and or adult males collected from both generations and mounted in either Hoyer's or Canada balsam, 91 were nonwinged and 7 were winged. Five winged forms were from the first generation and two winged males were from the second.

E. NATURAL ENEMIES

Parasites

Thirty-eight parasites were successfully reared from adult females. Seven species belonging to two hymenopterous families were found. Encyrtidae: Adelencyrtus sp., Microterys claripennis Compere, Plagiomerus cyaneus (Ashmead); Eulophidae: Ablerus clisiocampae (Ashmead), Aphytis sp., Marietta mexicana (Howard) (hyperparasite), and "probably" Physcus varicornis (Howard). Of the parasites reared and identified, 70% were Aphytis sp. The parasites were present from the last week of June through the first week of September (1972).

Associated Acarina

Five species of mites belonging to five families were found associated with C. kosztarabi. These were collected and mounted in Hoyer's by the author. These are as follows, Acaridae: Thyreophagus entomophagus (Lab.); Bdellidae: Bdella sp.; Hemisarcoptidae: Hemisarcoptes malus (Shimer); Tarsonemidae: Tarsonemus confusus Ewing; Tydeidae: Triophydeus sp.

The mite specimens were collected only from under the scale covers and found being associated with live adult females, deposited eggs and the immature stages. The mite Thyreophagus entomophagus is recorded as a scavenger feeding on dried insects, dead scale insects and their cast skins (Baker and Wharton, 1955). The family Tarsonemidae contains species of predators, scavengers and plant feeders. The collected species, Tarsonemus confusus, was actually found under a cover where eggs and first instars were present indicating possible predation. The other three families, Tydeidae, Hemiscaroptidae and Bdellidae, have been found to be predators on small insects. Specifically the mite Hemisarcoptes malus is known as a scale insect predator, feeding on eggs and scale insects, and occasionally its numbers have been great enough to significantly reduce scale insect populations. Baker and Wharton (1955) record 8 species of scale insects preyed upon by this mite, all belonging to the family Diaspididae, including one Chionaspis, C. salicis (L.) from from Germany.

F. MORPHOLOGY OF CHIONASPIS KOSZTARABI TAKAGI AND KAWAI

ADULT FEMALE

Plate 8

Chionaspis kosztarabi Takagi and Kawai, 1967:35.

Scale cover: Oystershell-shaped, dirty white to light grey. Measurements of 10 covers, 1.58 (1.10-2.10) mm long, and 0.80 (0.50-1.30) mm wide at broadest area. Test composed of terminal pale yellow first exuviae, 2.5Y/8/4, comprising 1/6 of entire test, and larger brown second exuviae covered by the secreted wax. A white mark remains on the plant material when the cover is removed.

DESCRIPTION

Body fusiform (fig. A) to pearshaped, about 875 (705-1225) long and 470 (390-606) wide, color without eggs yellow 7.5YR/6/10, derm membranous except for sclerotization on pygidium.

Pygidial margin (figs. B, C_1, & C_2): Triangular, acute with sclerotized lobes. Median lobes large and prominent, 16.3 (14.8-17.3) long, triangular in shape, margins serrate and yoked together by elongate basal zygosis. Second lobes well defined, usually bilobed, inner lobule well developed and serrated on outer margin; outer lobule indistinct and sharply triangular. Third lobe reduced to an indistinct sclerotized area. Gland spines, stout and tacklike setae, and macroducts present.

DORSAL SURFACE

Microducts: Few scattered one-barred microducts (fig. D), 9.37 (8.78-9.76) long and 1.46 (0.98-1.95) wide on meso- and metathorax and 2 to 6 submedially on segments I, II and III. Two-barred microducts (fig. E) marginally, 9.51 (8.65-11.1) long and 3.33 (2.47-3.71) wide

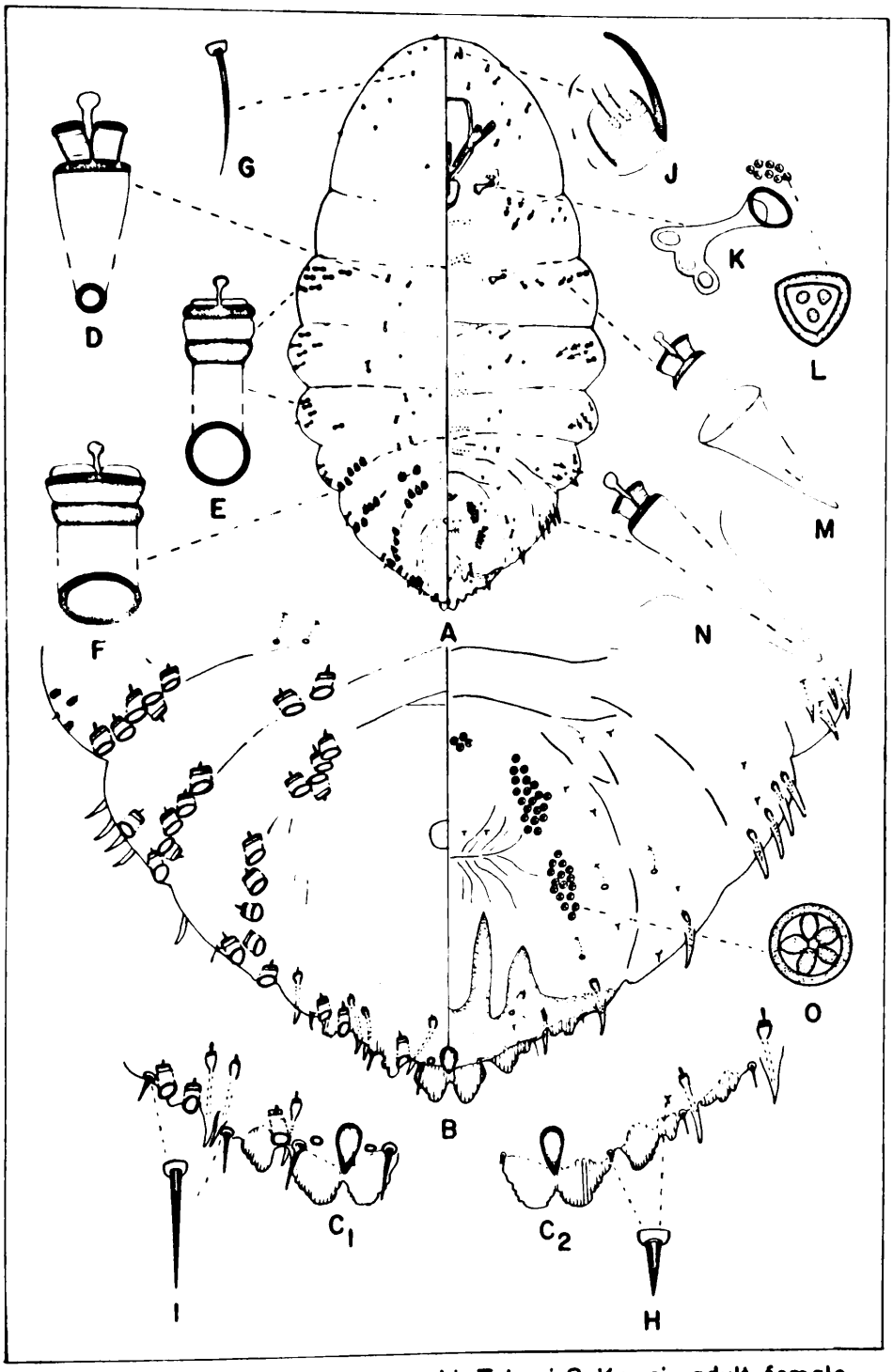

Plate 8.- Chionaspis kosztarabi Takagi & Kawai, adult female

along metathorax and becoming somewhat larger on segments I, II, and III, 10.3 (8.65-12.4) long and 3.96 (2.47-4.94) wide.

Macroducts (fig. F): Two-barred, 13.1 (11.1-14.8) long and 6.30 (4.94-7.41) wide, arranged in submedian and marginal groups on each half of the body on segments III, IV and V as follows: submedian: III, absent; IV, 1 to 4 (2.68); V, 2 to 5 (3.50); and rarely 1 or 2 on segment VI; marginal: III, 4 to 8 (5.18); IV, 3 to 6 (4.91); V, 3 to 5 (4.59). Marginal macroducts not in groups: 2 each on segments IV and V; 4 on segment VI and 2 on segment VII.

Setae: Few slender hairlike setae (fig. G), 7.32 (4.88-11.7) long at cephalic region. Short tacklike setae (fig. H), 1.30 (0.98-1.98) long marginally and submedially on first abdominal segments. Stout marginal setae (fig. I), 15.3 (12.7-18.5) long on segments V, VI, VII, and VIII.

Anal area: Anal opening elliptical, 9.51 (7.41-12.4) long and 12.4 (9.88-14.8) wide, removed ca. 8 times the length of the median lobes from pygidial apex. Small sclerotized porelike opening at base of each median lobe.

VENTRAL SURFACE

Antennae (fig. J): Reduced to small sclerotized tubercles, 5.95 (3.90-7.81) long and 8.15 (6.18-9.88) wide at base, each with 1 lateral fleshy seta 13.4 (11.7-15.6) long, and 2 short terminal hairlike sensory setae about 3.76 (2.93-4.88) long. Distance between antennal bases 54.1 (44.5-66.7).

Clypeolabral shield: Length 117 (91.4-133); width 53.6 (44.5-66.7).

Labium: Cupshaped, length 38.2 (34.6-42.0); width 40.9 (32.1-46.9).

Legs: Absent.

Spiracles: Thoracic spiracles with narrow bar supporting the opening; anterior spiracle (fig. K) 24.0 (22.2-24.7) long, atrium 5.93 (4.94-6.18) wide each with 3 to 18 (7.86) associated trilocular pores (fig. L) 3.85 (3.42-3.90) in diameter; posterior spiracle similar in shape, slightly smaller in size, 23.2 (18.5-29.6) long each with 1 to 3 (1.77) associated trilocular pores.

Gland tubercles (fig. M): Spinelike 9.61 (7.41-11.1) long and 3.02 (2.47-4.94) wide at base, with associated one-barred microducts projecting in each tubercle, submarginally, usually in groups of 2 to 4 posterior of each anterior spiracle (sometimes absent), on meso- and metathorax and 0 to 6 on abdominal segments I and II.

Gland spines (fig. N): Long marginal gland spines 19.9 (11.0-22.2) long and 5.19 (3.71-7.41) wide at base, each with associated one-barred microducts located on each side of body as follows: III, 1 to 5; IV, 3 to 6; V, 1 or 2; VI and VII, 1 on each segment.

Microducts: One-barred microducts (fig. D), 9.36 (7.81-11.2) long and 1.56 (0.98-1.95) wide, 6 to 12 scattered on cephalic region, 2 to 4 submedially on meso- and metathorax and on segments I, II, and III. Two-barred microducts (fig. E), 8.52 (7.41-9.88) long, and 2.79 (2.47-3.71) wide marginally and submarginally on meso- and metathorax becoming somewhat larger on segments I, II, and III, 9.63 (8.65-9.88) long and 3.21 (2.47-3.71) wide.

Macroducts: Absent.

Setae: Few slender hairlike setae (fig. G), 8.70 (4.88-18.5) long

on cephalic area. Shorter tacklike setae (fig. H), 1.78 (1.46-2.93) long scattered submarginally on thorax; two paired submarginal rows on abdomen; and two paired submedian rows from segment I to apex of vulvar opening. Stouter marginal setae (fig. I), 10.2 (5.85-12.7) long laterad of lobes VI and VII and 1 ca. 4.88 long laterad of each median lobe.

Minute spinelike structures: Medially in transverse rows extending from base of labium to apex of vulva.

Vulvar area: Vulvar opening located about middle of pygidium, paravulvar sclerosis distinct. Quinquelocular perivulvar pores (fig. 0) in 5 groups: median, 7 to 14 (9.45); anterolateral, 15 to 32 (19.9); and posterolateral, 13 to 23 (17.3); each pore 4.54 (3.90-4.88) in diameter.

MATERIAL STUDIED

Measurements and ranges were taken from 1 specimen from each of the following lots: on Fraxinus americana, A & M College, Mississippi (MSU); Chapel Hill, North Carolina (USNM): Wood, Co., Ohio (VPI&SU); Cheltenham, Pennsylvania (VPI&SU); Morristown, Pennsylvania (USNM); and Montgomery County, Virginia (VPI&SU); on F. nigra, Ottawa County, Ohio (VPI&SU); on Fraxinus sp., Monroe County, Georgia (UGAES); Baltimore, Maryland (VPI&SU); and Anderson, South Carolina (USNM).

HOST AND DISTRIBUTION

Probably generally distributed in Eastern North America where Fraxinus spp. are present, occurring on bark of trees. Slides on hand indicate its presence in the following states: Georgia, Maryland, Mississippi, North Carolina, Ohio, Pennsylvania, South Carolina, and Virginia.

Illustrations were made from holotype slide (No. 0201) from Fraxinus

americana deposited at VPI&SU.

Chionaspis kosztarabi Takagi and Kawai

FIRST INSTAR

Plate 9

DESCRIPTION

Body (fig. A) elongate-oval, widest thoracic area narrowing caudally, slightly convex dorsally. Live specimens have distinct black lateral eyespots, colorless appendages, segmented abdomen bearing a pair long slender hairlike caudal setae which are 3/4 length of body. Color of live nymphs usually orange, 2.5YR/7/10, derm membranous. Mean body length of 10 specimens 249 (212-306) long and 135 (98.8-185) wide.

Pygidial margin (fig. B): Dorsally serrated. Ventrally with distinct lobelike projections; median lobe spinelike, 4.73 (3.90-5.86) long; second trilobed, median longer than laterals, each lobule usually rounded apically; third single, nipple-shaped. Abdominal spines, pair long anal setae and short tacklike setae present.

DORSAL SURFACE

Microducts (fig. C): Tubeshaped, 6.54 (5.37-8.78) long and 2.29 (1.46-2.93) wide, 2 submedian on each thoracic segment and 2 laterad of anal orifice slightly smaller, 5.70 (4.88-7.81) long and 2.96 (2.44-3.90) wide.

Macroducts: Occasionally 2 submedially on cephalic region, 6.41 (3.90-8.78) long, and 2.44 (0.98-2.93) wide. This duct is not consistently present or often occurs asymetrically.

Setae: Long slender hairlike setae (fig. D), 8.88 (5.85-11.7) long, 12 marginally at cephalothorax, 8.15 (5.37-9.76) long continuing somewhat shorter marginally at abdomen 4.61 (2.93-5.86) long. Shorter tacklike

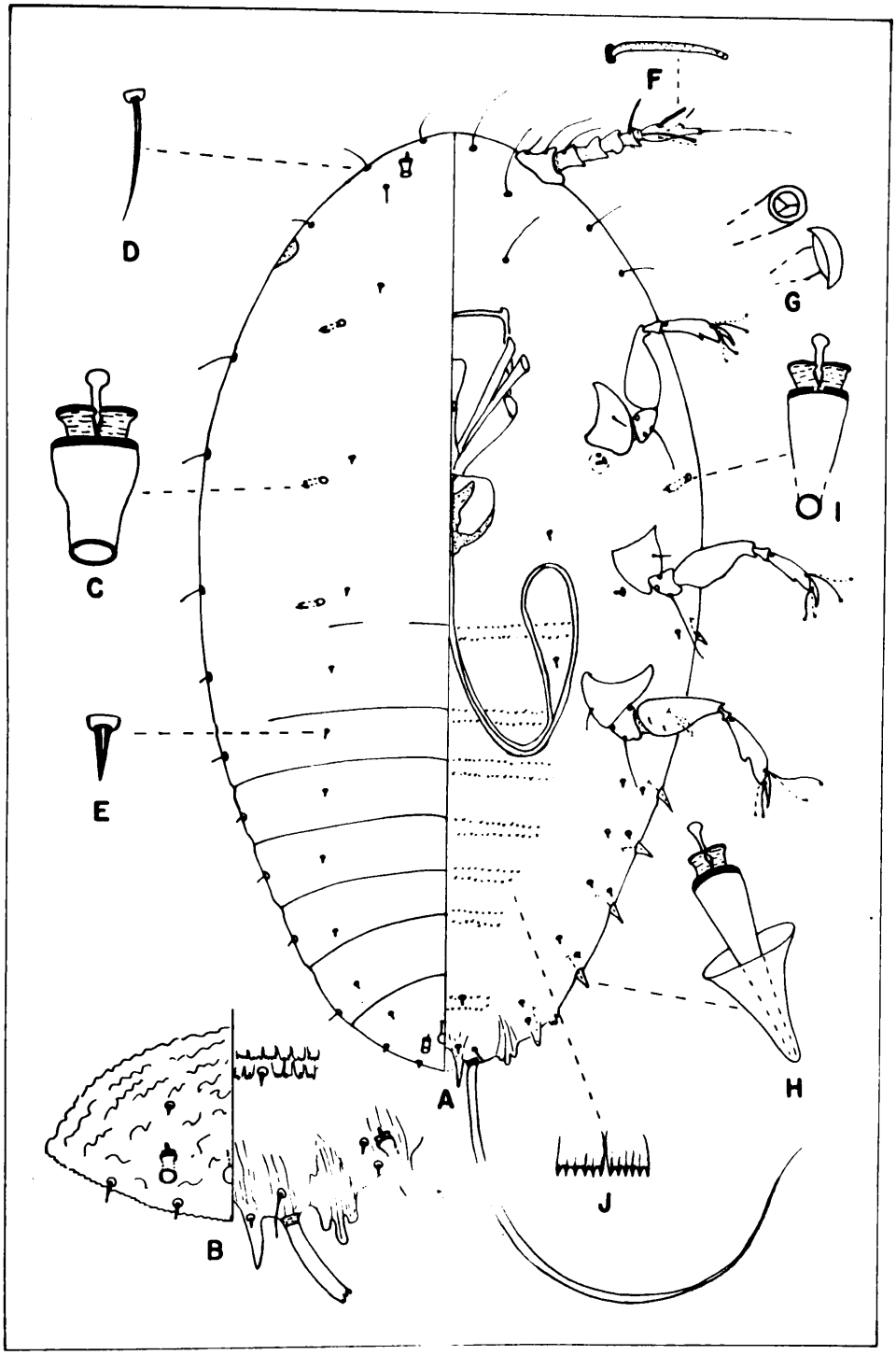

Plate 9.- Chionaspis kosztarabi Takagi & Kawai, first instar

setae (fig. E) 1.32 (0.98-1.95) long in two submedian rows length of body, somewhat longer cephalically than caudally.

Anal area: Anal orifice circular, 1.74 in diameter.

VENTRAL SURFACE

Eyes: Marginal, elongate lightly sclerotized areas, ovoid, 7.91 (7.41-9.88) long and 5.76 (4.94-7.41) wide.

Antennae: Six-segmented, 45.4 (42.0-49.4) long. Distance between antennal bases 32.1 (29.3-35.1). Scape 9.66 (7.81-10.7) long and 10.5 (9.76-11.7) wide. Segments II to VI: 6.88 (6.34-7.81), 5.71 (4.88-7.81), 4.83 (3.90-5.86), 3.91 (2.93-5.88), 16.9 (13.7-20.5) long respectively. Terminal segments each with 1 hairlike seta, 21.2 (11.7-24.4) long, and 4 fleshy sensory setae (fig. F) 11.4 (9.76-13.7) long. Setae on other segments of each antenna: I, 2 hairlike setae, 16.8 (8.78-33.2) long; II, 1 hairlike seta; III, absent; IV, absent; V, 2 fleshy setae.

Clypeolabral shield: Length 46.3 (42.0-49.4); width 24.3 (22.0-27.2). Stylet loop about 162 (151-170) long.

Labium: Bowlshaped, 22.5 (19.8-24.7) long and 22.6 (19.8-24.7) wide.

Legs: Well developed, 4 digitules present on each leg. Small sensillum located on base of each trochanter and one sensilla on antero-distal margin of each tarsus.

Part of Leg	Lengths prothoracic	Lengths mesothoracic	Lengths Metathoracic
Coxa	13.0(9.27-15.6)	13.6(11.7-15.6)	12.9(11.7-16.6)
Trochanter	7.13(5.86-9.76)	7.13(5.86-7.81)	7.13(4.88-8.78)
Trochanter seta	15.3(13.7-18.5)	16.1(14.6-18.5)	14.2(12.7-17.6)
Femur	20.3(18.5-22.4)	22.7(19.5-23.4)	21.6(20.5-23.4)
Tibia	5.13(3.90-5.86)	5.08(4.88-6.83)	5.71(4.88-6.83)
Tarsus	14.0(10.7-17.6)	15.2(12.7-17.6)	17.0(13.7-19.5)
Tarsal digitule	13.2(10.7-14.6)	13.7(12.7-14.6)	13.2(11.7-15.6)
Claw	8.39(6.83-9.76)	8.19(6.83-8.78)	8.34(5.86-9.76)
Claw digitule	10.5(8.78-11.7)	10.2(8.78-11.2)	10.6(8.78-12.2)
Entire leg	62.5(51.9-71.6)	62.5(51.9-69.2)	67.6(61.8-74.1)

Spiracles: Mushroom-shaped, anterior pair (fig. G) about 6.67 (4.88-8.78) long, atrium 3.17 (2.44-3.90) wide, each with 1 associated trilocular pore 2.88 (2.44-3.90) in diameter; posterior similar in shape and size, trilocular pores absent.

Abdominal spines (fig. H): Seven pairs marginal spinelike projections, 5.19 (3.90-5.86) long and 2.77 (1.95-3.90) wide at base, each with an associated one-barred microduct, on thorax and abdomen.

Microducts (fig. I): Coneshaped, 7.17 (5.86-8.78) long and 1.80 (1.46-1.95) wide, 2 to 6 submarginally on thorax.

Macroducts: Absent.

Setae: Long slender hairlike setae (fig. D) 22.7 (16.6-26.4) long, 4 to 6 submedially cephalic area, 1 marginally at apex, 2 marginally at each eyespot, and 1 shorter, 6.15 (3.90-8.78) long at base of each long anal seta. Short stout setae (fig. E) 2.06 (0.98-3.42) long, 4 submedially and 2 marginally on thorax, 6 pairs in a longitudinal row submarginally on each half of abdomen, 1 on base of each median anal lobe.

Minute spinelike structures (fig. J): Paired transverse rows medially on thorax and abdomen.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots collected at Montgomery County, Virginia by P. A. Willoughby, in 1972 on Fraxinus americana, 2(25), June 2, PAW036c,o; 1(4), June 14, PAW042d; 1(21), Aug. 10, H08; 2(23), Aug. 17, PAW090a,c; 1(9), Aug. 24, PAW091a; 1(4), Aug. 31, PAW092a; 1(4), Sept. 7, PAW093b; 2(2), Sept. 14, PAW094a,b.

Chionaspis kosztarabi Takagi and Kawai

SECOND INSTAR FEMALE

Plate 10

DESCRIPTION

Body (fig. A) fusiform 366 (291-519) long and 201 (155-321) wide at mesothorax, pygidial lobes distinctly projecting beyond margin, black lateral eyespots visible in live specimens, color bright yellow 5Y/8/8, derm membranous except for sclerotization on pygidium. Cover composed of light tan first exuviae and secreted white wax.

Pygidial margin (fig. B): Broadly triangular with sclerotized prominent lobes. Median lobes, triangular, 10.5 (9.76-11.2) long diverging mesally toward flat apex, margins serrate, lateral margins longer than inner and sloping, pegshaped zygosis yoking lobes together sometimes evident. Second lobes bilobed, closely appressed, lobules often apically notched. Third lobes distinguishable by sclerotization and slight protuberance of macroducts. Gland spines stout, needle-like, short tack-like setae, and macroducts present.

DORSAL SURFACE

Microducts: Absent.

Macroducts (fig. C): Two-barred marginal macroducts, 12.4 (11.7-13.7) long and 5.47 (4.88-6.83) wide, at segmental lines of segments IV to VII and sometimes III.

Setae: Eight slender setae (fig. D), 3.90 (2.93-5.86) long marginally on cephalic area, becoming shorter and tacklike on thorax, 2.44 (1.46-3.42) long, increasing in size on abdomen 3.51 (1.95-4.39); 5 short tack-like setae (fig. E) ca. 0.98 long in longitudinal submedian row on each

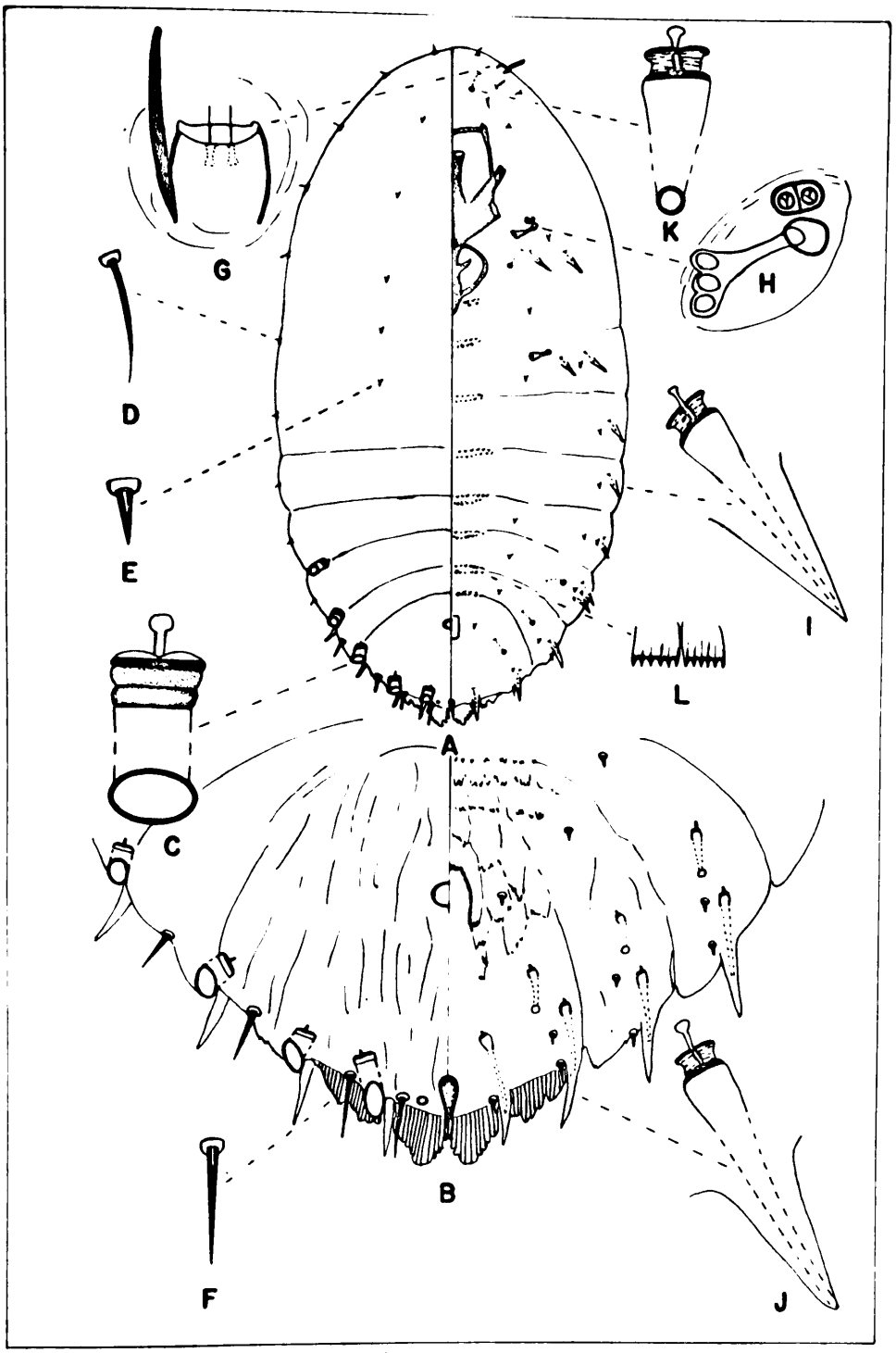

Plate 10.- Chionaspis kosztarabi Takagi & Kawai, second instar female

body half at cephalothorax. Stout needle-like setae (fig. F), 9.66 (7.81-12.7) long at margin of each lobe of segments IV to VII.

Anal area: Sclerotized anal tube elliptical, 4.15 (2.93-4.88) long and 5.61 (4.88-6.34) wide, located at 2/3 the distance on pygidium from its apex.

VENTRAL SURFACE

Antennae (fig. G): Present as 1-segmented sclerotized tubercles, 5.37 (3.90-6.83) long and 4.98 (3.90-5.86) wide at base,each with 1 stout fleshy lateral seta 8.88 (7.81-9.76) long, and 2 short hairlike terminal setae 2.77 (1.95-3.42) long. Distance between antennal bases 42.0 (35.1-53.7).

Clypeolabral shield: Length 68.4 (61.7-76.6); width 33.6 (32.1-37.1)

Labium: Cupshaped,26.0 (19.8-29.6) long and 30.0 (27.2-34.6) wide.

Legs: Absent.

Spiracles: Clubshaped, anterior spiracles (fig. H) 16.3 (12.7-18.5) long, atrium 4.10 (3.90-4.88) wide, each with 1 or 2 associated trilocular pores, 3.27 (2.44-3.90) in diameter; posterior spiracles similar in shape, 15.7 (13.7-16.6) long, pores absent.

Gland tubercles (fig. I): Spinelike,8.88 (7.81-9.76) long and 2.54 (1.95-3.90) wide, basally with associated one-barred microduct, 2 basad each anterior and posterior spiracles, marginally or submarginally 1 at each side of body on segments I, II, and 1 or 2 on segment III.

Gland spines (fig. J): Marginal, 12.6 (11.2-15.6) long and 3.37 (2.44-3.90) wide, basally with associated one-barred microducts; 4 on segment IV, 2 on each segment V to VII.

Microducts: One-barred (fig. K), 7.45 (5.86-8.78) long and 1.46 (0.98-1.95) wide; submedially, 2 anterior to clypeolabral shield, 1 or 2 posterior each anterior spiracle; submarginally, 2 on each segment IV to VI.

Macroducts: Absent.

Setae: Few long slender setae (fig. D) 5.37 (2.93-6.83) at cephalic region anterior to mouthpart. Three short tacklike setae (fig. E) 0.98 (1.16-1.46) long, in submedian longitudinal row on each side of thorax, about 6 in submarginal row along each side of abdomen, 8 forming two submedian longitudinal rows on segment III to laterad of vulva. Stout needle-like setae (fig. F) 5.47 (3.90-7.81) long, adjacent of gland spines at pygidium.

Minute spinelike structures (fig. L): Median transverse rows on thorax and abdomen.

Vulvar area: Reticulated pattern with elongate opening about 5.53 (3.90-7.81) wide.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Fraxinus americana, 1(4), Wood County, Ohio, July 8, 1961, Coll. M. Kosztarab, VPI&SU, 0201; the remainder collected at Montgomery County, Virginia by P. A. Willoughby in 1972: 1(13), June 13, PAW046c; 2(6), June 14, PAW042d; 1(7), June 23, PAW040d; 3 (22), June 30, PAW042a,b,c; 1(1), July 7, PAW049a; 1(14), Aug. 31, H11; 1(18), Sept. 14, H13a.

Chionaspis kosztarabi Takagi and Kawai

SECOND INSTAR MALE

Plate 11

DESCRIPTION

Body (fig. A) ovoid early second instar to elongate-oval late second instar, 392 (296-464) long and 210 (180-242) wide, black lateral eyespots distinct on live specimens, color yellow 5Y/8/8, derm membranous without visible sclerotization. Cover composed of terminal dorsal pale yellow colored first exuviae and secreted frosty white wax dorsally and ventrally late at development.

Pygidial margin (fig. B): Subcircular with many small lobes. Median lobes widely separated with parellel sides, about 5.27 (4.88-6.83) long, apex notched once medially with inner lobule apically toothed and apex of lateral lobule rounded. The other lobes as follows: 2 short wide lobules with toothed apex, 1 large prominent lobe rounded at apex, about 6 often indistinguishable lobules each usually apically rounded. Needle-like setae, short tacklike setae, one-barred microducts present.

DORSAL SURFACE

Microducts: Two kinds. One-barred microducts (fig. C), 6.49 (5.86-6.83) long and 1.56 (0.98-1.95) wide, submedially 2 to 4 at cephalic region, transverse row of 1 to 3 on each side of prothorax; submedially 2 to 6 on posterior region of thorax. Two-barred microducts (fig. D), 6.64 (5.86-8.30) long and 2.79 (1.95-3.90) wide on thorax and somewhat larger on abdomen, 7.03 (5.86-9.27) long and 3.08 (2.44-3.90) wide, numerous; 5 groups of 3 or 4 ducts in transverse diagonal rows on each side of body from mesothorax to anterior region of abdomen, posterior

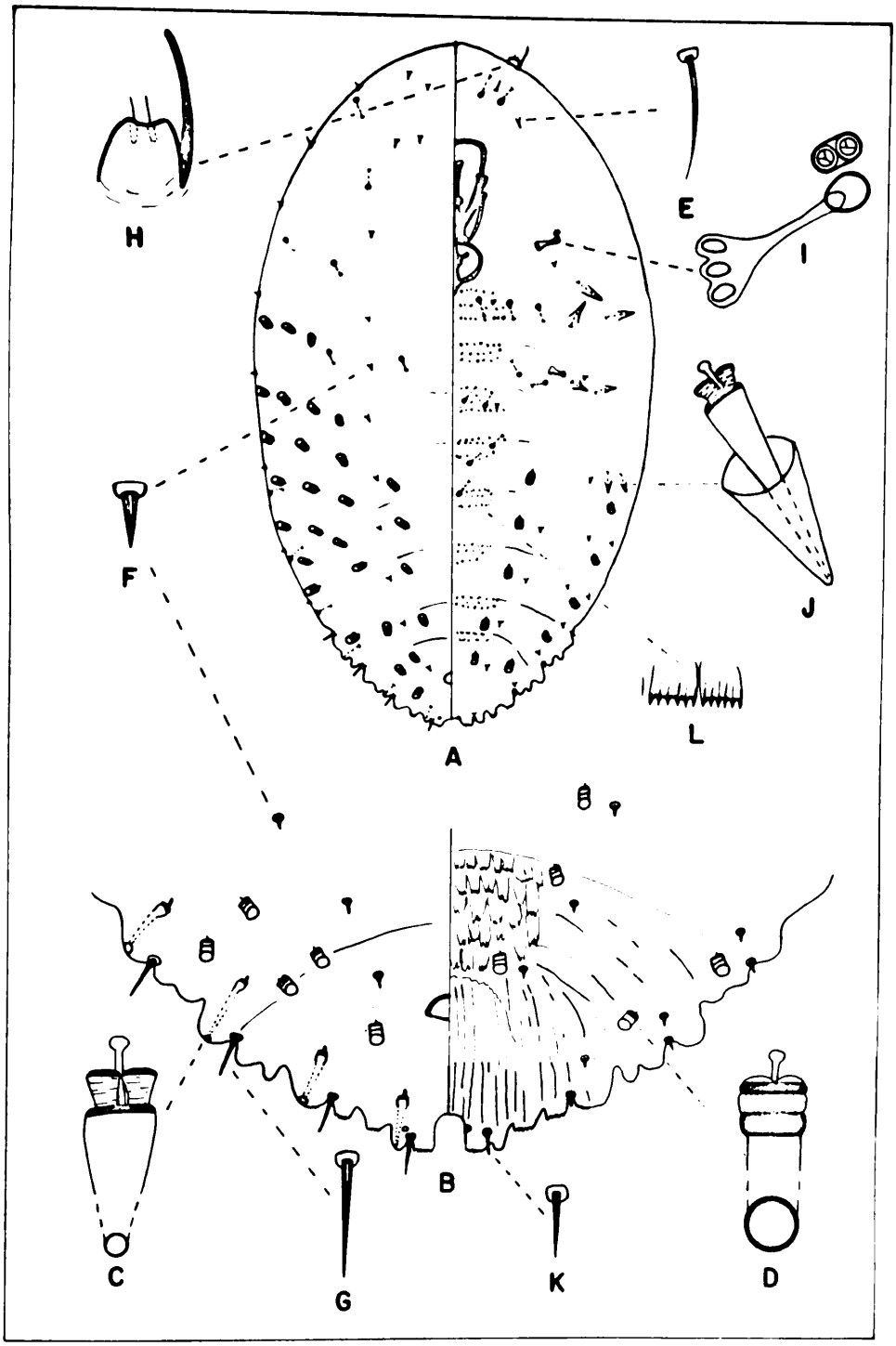

Plate II.- Chionaspis kosztarabi Takagi & Kawai, second instar male

abdomen with about 6 transverse rows of 2 or 3 microducts in each row.

Macroducts: Absent.

Setae: Few slender setae (fig. E) 5.17 (3.42-7.81) long submedially at cephalic margin. Short tacklike setae (fig. F) ca. 0.98 long in two longitudinal submedian rows extending from thorax to laterad of anal opening; a row marginally on each side of thorax and abdomen to pygidial area, 1.80 (0.98-2.93) long. Four needle-like setae (fig. G) 5.81 (4.39-6.83) long at margin of pygidium, longer setae at median lobes, 6.64 4.88-8.78) long.

Anal area: Sclerotized anal opening elliptical, 4.15 (3.90-4.88) long and 5.52 (3.90-6.83) wide, displaced 6 times its length from pygidial apex.

VENTRAL SURFACE

Antennae (fig. H): Reduced to 1-segmented tubercles, 4.53 (3.37-5.86) long and 5.17 (4.88-7.81) wide at base, each antenna with 1 lateral fleshy seta 9.17 (7.81-10.7) long and 2 short terminal hairlike setae ca. 2.44 long. Distance between antennal bases 60.1 (45.9-82.0).

Clypeolabral shield: Length 69.4 (64.2-76.6); width 34.4 (27.2-42.0).

Labium: Ovate, 27.4 (22.2-34.6) long and 31.6 (25.9-37.1) wide.

Legs: Absent.

Spiracles: Clubshaped, anterior spiracle (fig. I) 18.2 (16.1-19.5) long, atrium 4.29 (3.90-4.88) wide, each with 1 to 3 associated trilocular pores 3.22 (2.93-3.90) in diameter; posterior spiracles same in shape, 16.9 (15.6-17.6) long and 4.15 (3.90-4.88) wide, without associated pores.

Gland tubercles (fig. J): Coneshaped, 9.31 (7.81-10.7) long and

3.66 (2.93-3.90) wide, each tubercle with associated one-barred microduct, submarginal, a group of 2 or 3 posterior each anterior spiracle, 2 at each posterior spiracle and 0 to 2 on segment II.

Gland spines: Absent.

Microducts: One-barred (fig. C) 6.74 (5.37-8.78) long, and 1.46 (0.98-1.95) wide; submedially, 2 posterior of each antenna, 2 or 3 mesally with first group of gland tubercles, 1 or 2 at each posterior spiracle and a longitudinal row on each body side of 3 to 6 extending from metathorax to mid-abdomen.

Macroducts: Absent.

Setae: Few scattered long slender setae (fig. E) 7.47 (3.42-11.7) long on cephalic area. Short tacklike setae (fig. F) ca. 0.98 long, 1 at each spiracle, 4 submedially on thorax, two longitudinal submedian rows and two paired rows marginally and submarginally on posterior half of abdomen. One needle-like seta (fig. K) 4.05 (2.93-4.88) long at base of each median lobe.

Minute spinelike structures (fig. L): Transverse rows medially on thorax and abdomen.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots, on Fraxinus americana, 1(1), Wood, County, Ohio, July 8, 1961, Coll. M. Kosztarab, VPI&SU, 0201; the following collected at Montgomery County, Virginia by P. A. Willoughby in 1972: 1(1), June 14, PAW042c; 1(6), June 23, PAW040b; 1(9), June 30, PAW044a; 1(8), July 7, PAW049b; 1(3), July 14, PAW052a; 1(5), Sept. 14, H13a; 1(7), Sept. 21, PAW084b; 1(3), Oct. 5 PAW064b; on Fraxinus sp, 1(1), Pike County, Georgia,

Oct. 7, 1969, Coll. H. H. Tippins, UGAES, HHT-179-69.

Chionaspis kosztarabi Takagi and Kawai

MALE PREPUPA

Plate 12

DESCRIPTION

Body (fig. A) fusiform, live specimens with visible lateral black eyespots, color yellow orange 10YR/7/8, found enclosed within cover of secreted white wax attached to plant material by terminal first exuviae. Measurements of 10 mounted specimens, 520 (489-603) long and 177 (148-232) wide at mesothorax.

Body setae: Short tacklike setae (fig. B) on male prepupae. Dorsally in regular pattern entire body. About 16 dorsal head setae (dhs), 3.03 (1.95-4.88) long, 2 at head apex, 1 at base of each antenna, 3 pairs submarginally to marginally of each eyespot. A longitudinal row of thorax dorsal setae (tds) submedially on mesothorax and metathorax continuing as abdominal dorsal setae (ads), one pair per segment, about 1.50 long (less 0.98-1.95) long. Two single rows thorax dorsal setae (tds) 1.66 (0.98-1.95), marginally, continuing as abdominal pleural setae (aps) (fig. C), 3.51 (1.95-3.90) long on abdomen. Ventrally few setae present, about 6 ventral head setae (vhs), 3.32 (1.95-5.86) long, submarginally on head, absent on thorax. Four abdominal ventral setae (avs) 1.71 (0.98-2.93) long,in a longitudinal row submedially on segments IV to VII. Minute spinelike structures (fig. D) in transverse longitudinal rows on thorax and abdomen.

Head: Not clearly separated from prothorax, narrowing toward apex without any ridges.

Antennae: Long parellel-sided structure rounded at apex, and tele-

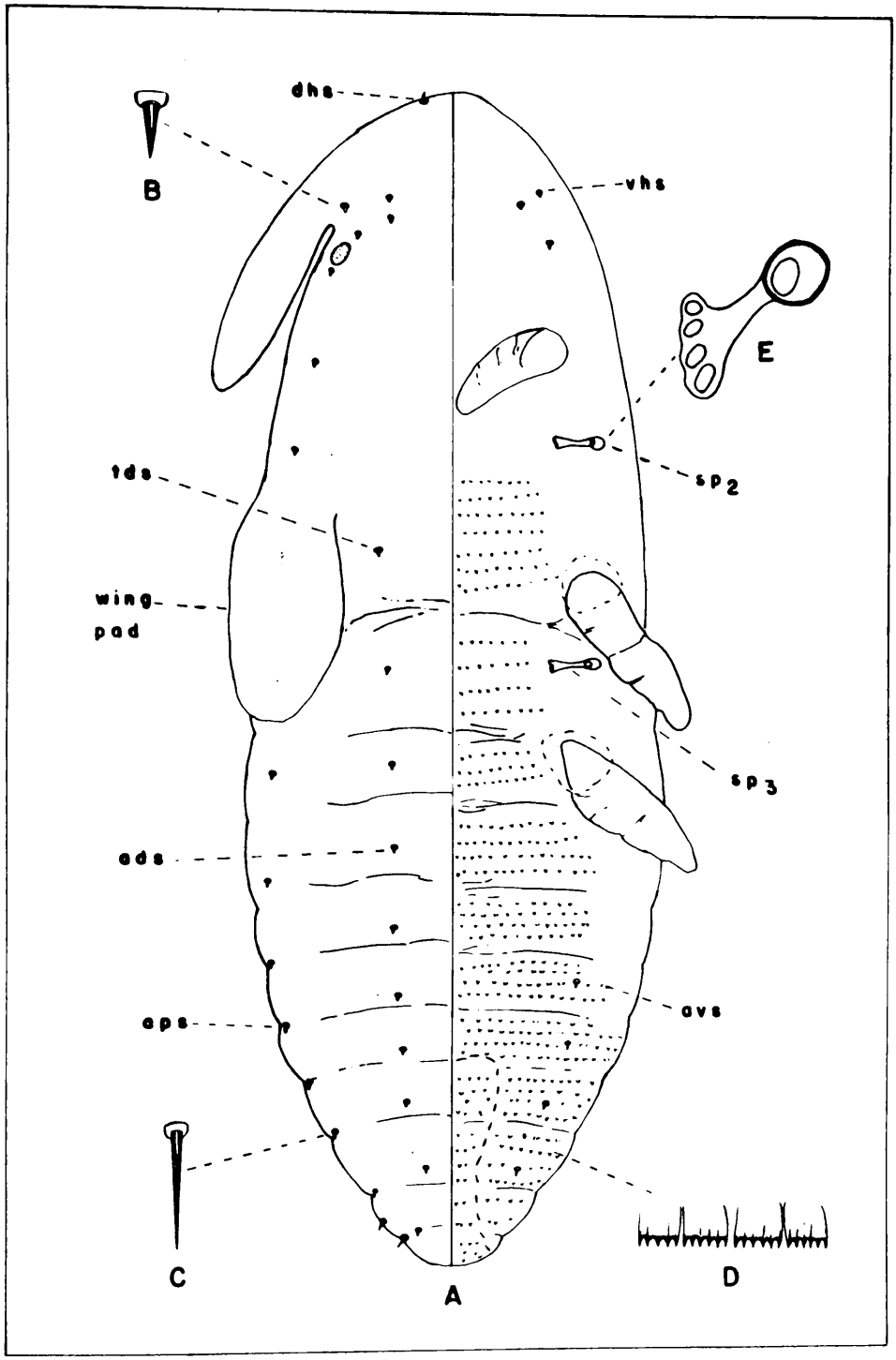

Plate 12.- Chionaspis kosztarabi Takagi & Kawai, male prepupa

scoping segments indistinct, 125 (98.8-165) long and 27.4 (22.2-46.9) wide at base. Distance between antennal bases 65.3 (49.4-81.5).

Thorax: Fused with head and abdomen, about 180 (161-203) long and 177 (148-232) wide.

Wing pads: Rarely present, budlike, 128 long and 66.7 wide (1 specimen).

Spiracles (fig. E): Submarginally on thorax, each 19.9 (17.3-24.7) long and atrium 7.14 (6.18-8.65) wide, both without associated pores.

Legs: Segmentation incomplete except for coxae, without setae. Length and width at base: prothoracic leg 68.9 (54.3-86.5) long and 29.2 (24.7-37.1) wide; mesothoracic leg 85.7 (54.3-143) long and 30.1 (24.7-29.6) wide; and metathoracic leg 87.2 (59.3-143) long and 30.4 (24.7-32.1) wide.

Abdomen: Eight segments are indistinctly present, about 224 (185-257) long and 172 (128-203) wide. There is a tubeshaped structure of the developing aedeagus internally in segments V to VIII.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots collected at Montgomery County, Virginia by P. A. Willoughby in 1972: on Fraxinus americana, 1(1), July 7, H03; 1(2), July 14, PAW052c; 1(1), Sept. 21, H14b; 2(2), Sept. 28, PAW081c, H15b; 1(1), Oct. 19, H18a; 1(3), Oct. 25, H20b.

Chionaspis kosztarabi Takagi and Kawai

MALE PUPA

Plate 13

DESCRIPTION

Body (fig. A) very elongate, widest at abdomen narrowing anteriorly with long antennal sacs compressed laterally along body margin and tapering posteriorly into a protruding cylindrical genital segment. Live specimens pale orange 5YR/7/8, enveloped by secreted white wax with their terminal first exuviae connecting test to plant material. Measurements of 10 mounted specimens, 559 (514-632) long and 151 (121-175) wide at mesothorax.

Body setae: Short tacklike (fig. B) in a uniform pattern on dorsum. About 14 dorsal head setae (dhs) 3.86 (1.95-5.86) long, 1 at anterior margin of each antennal sac, 2 marginally or submarginally at each antennal base, 2 submedially and 2 submarginally posterior area on each side of the head. Five dorsal thoracic setae (dts) about 1.22 (0.98-1.95) long, 6 submarginally and 4 submedially on thorax. Four abdominal pleural setae (aps) (fig. C) 4.50 (3.42-7.41) long, marginally 1 each on last four segments. Abdominal dorsal setae (ads) 2.49 (1.95-2.93), numerous, 9 in longitudinal row on each body half submarginally the length of abdomen 2 of which are a pair on eighth segment, two longitudinal rows 7 each submarginally on abdominal segments. Two setae on genital segment (gts) 1.41 (0.98-2.93) long, found submedially on base of genital segment. Tacklike setae scarce on ventrum. About 4 ventral head setae (vhs) 2.83 (1.95-3.90) long, submedially on anterior head region. Eight abdominal ventral setae (avs) 2.06 (0.98-3.90) long, forming two longi-

tudinal rows submedially on segments IV to VII. Minute spinelike structures (fig. D) in transverse longitudinal rows on thorax and abdomen.

Head: Broadly joined to thorax, apically rounded. Postocular ridge (pocr) and pronotal ridge (prnr) indistinctly sclerotized.

Eyes: Dorsal simple eyes (dse) faintly visible, 19.2 (12.4-29.6) in diameter and separated by ca. 37.1; ventral simple eyes (vse) distinct on live specimens and in specimens mounted in Hoyer's, indistinct in stained specimens mounted in Canada balsam, 19.7 (9.88-27.2) in diameter and separated by ca. 12.4.

Antennae: Long slender antennal case, 192 (161-215) long and 22.0 (19.8-24.7) wide at base narrowing apically, each case enveloping 10-segmented adult antenna with many long antennal setae visible. Distance between antennal bases 49.9 (37.1-64.2).

Thorax: Widely joined at head and at abdomen, about 165 (143-173) long from apex to first abdominal segment and 152 (121-175) wide at mesothorax.

Wing pads: Elongate, spatula-like, rarely present, none measured.

Spiracles (fig. E): Two pairs submarginally on thorax, each 19.9 (19.8-23.5) long and atrium 7.63 (7.41-8.65) wide, both pairs without associated pores.

Prothorax: Dorsally and ventrally without recognizable structures.

Mesothorax: Dorsally, prescutum (prsc), scutum (sct) and scutellum (scl) slightly sclerotized. Ventrally, basisternum (stn_2) present. Pores absent.

Metathorax: No recognizable structures or pores detected.

Legs: Sclerotized saclike case enclosing developing legs; coxa,

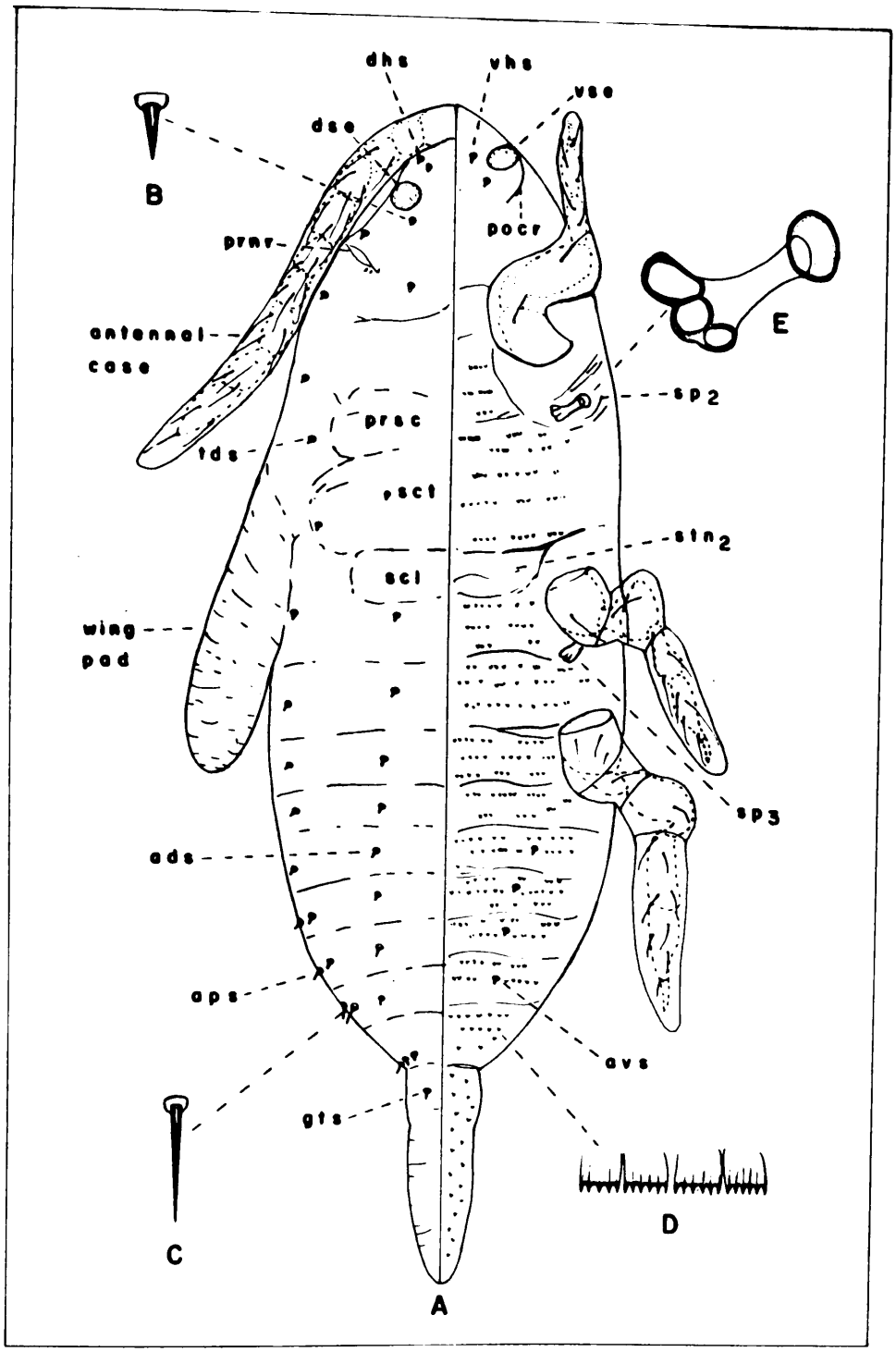

Plate 13.- Chionaspis kosztarabi Takagi & Kawai, male pupa

trochanter, femur, tibia, claws and associated setae visible through case. Lengths and widths of pupal leg cases prothoracic to metathoracic: 145 (121-161) long and 33.1 (27.2-41.9) wide; 157 (133-185) long and 35.8 (32.1-39.5) wide; and 179 (143-210) long and 36.6 (27.2-46.9) wide. Prothoracic legs folded anteriorly toward head, mesothoracic and metathoracic legs positioned laterally toward abdomen.

Abdomen: United broadly with thorax gradually tapering and then terminating in expanded cylindrical genital structure, about 189 (153-235) long and 146 (124-180) wide at base, not including genital segment. Abdomen without pores.

Genital segment: Cylindrical, wide at base narrowing to blunt apex, 107 (91.4-123) long and 40.5 (32.1-46.9) wide at base.

MATERIAL STUDIED

Description and measurements were taken from specimens from each of the following lots collected in Montgomery County, Virginia by P. A. Willoughby in 1972, on Fraxinus americana, 1(1), July 7, H03; 2(5), Sept. 21, H14a,b; 1(7), Sept. 28, H15a; 1(3), Oct. 5, H16b; 2(12), Oct. 12, H17a,b; 1(6), Oct. 19, H18a; 1(2), Oct. 25, H20a.

Chionaspis kosztarabi Takagi and Kawai

ADULT MALE

Plate 14

DESCRIPTION

Small fusiform body terminating in a long needle-like stylus (fig. A), large black prominent eyespots anteriorly, appendages conspicuously long and slender, filiform 9- or 10-segmented antennae and three pair of well developed legs, bushy due to many associated setae. Dimorphic condition present consisting of wingless individuals and winged specimens bearing one pair of long membranous wings. Color pale orange 5YR/7/8, or golden brown 2.5Y/7/8, derm membranous except for areas of sclerotization on head and mesothorax. Male test elongate, parallel-sided with and without median carina, ca. 6 mm long and 2 mm wide, composed of secreted white frosty wax and light brown first exuviae, ca. 3 mm long and 2 mm wide. Measurements of 8 mounted apterous males, 690 (637-755) long and 128 (111-130) wide at mesothorax.

Body setae: More numerous dorsally than ventrally. Dorsally: Dorsal head setae (dhs) long and stout with prominent bases, 16.2 (9.76-19.5) long, a pair at apex along midcranial ridge (mcr), 3 along each dorsal lateral branch of midcranial ridge (lmcr), these forming an inverted "Y" pattern; 1 on each posterior corner of median crest (mc); 2 genal setae (gs), 5.42 (3.42-8.78) long, submarginally on each gena; shorter tacklike setae, 3.96 (1.95-6.83) long in a pattern, about 5 submarginally along each side of thorax including setae of tegula (teg), 2 submedially on scutellum (scl); abdominal dorsal setae (ads) tacklike, 4.69 (2.93-5.86) long, in four longitudinal rows, 8 forming a marginal

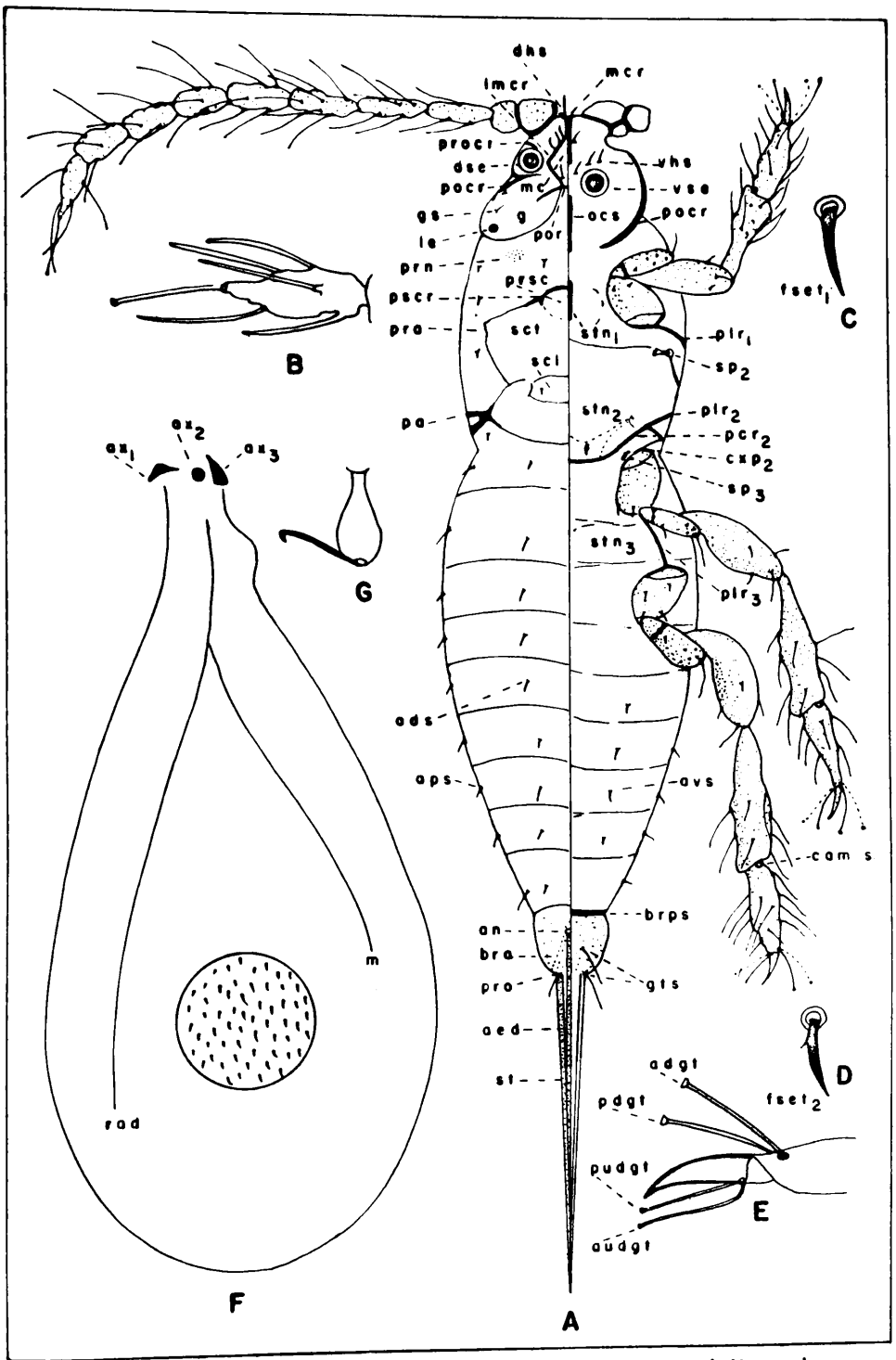

Plate 14.- Chionaspis kosztarabi Takagi & Kawai, adult male

row on each body half, and about 8 each in two submedian rows extending to genital segment; genital segment setae (gts) long and hairlike 21.0 (12.7-26.4) long, 2 at base of stylus. Ventrally: Setae less numerous; ventral head setae (vhs) long and stout, 22.3 (18.5-27.3) long; a pair medially on midcranial ridge and 3 forming a diagonal row above each ventral simple eye (vse) which forms a "V-shaped" pattern; setae absent from thorax; abdominal ventral setae (avs) tacklike, 4.39 (2.93-6.83) long, two longitudinal rows on segments IV to VII; 4 in marginal row and 4 in submedial row; genital setae (gts) long hairlike, 20.5 (17.3-23.4) long, 2 submedially on posterior half of genital segment and 2 marginally at base of stylus.

Head: Retracted into thorax dorsally, more distinct ventrally, rather short and wide with well developed ridges, 2 pair of eyes and long setae; head, 42.6 (42.0-44.5) long from vertex to postoccipital ridge (por) and 85.6 (79.0-93.9) wide across gena (g). Dorsally, midcranial ridge (mcr) extending from apex of head for a short distance medially before branching diagonally into dorsal lateral branches (lmcr) which extend to eye then extend back obliquely to join median postoccipital ridge (pocr), these ridges setting off a diamond-shaped, membranous median crest (mc). Gena (g) elliptical, positioned obliquely from postoccipital ridge (pocr) and separated laterally and posteriorly by genal suture (gs). Ventrally, eggshaped, nearly divided medially by two sclerotized structures; midcranial ridge extending from dorsal surface between antennae to about midpoint of ventral surface, and ocular sclerite (ocs) extending medially from between ventral simple eyes (vse) to posterior margin of head. Postoccular ridge (pocr) continuing from dorsal

surface and forms the posterio-lateral boundary of head.

Antennae: Long filiform, 9- or 10-segmented; the 9-segmented, 260 (198-306) long, antennal bases separated by 15.7 (12.4-17.3). Specimens collected indicate that the winged specimens have 10-segmented antennae while apterygotes are only with 9-segments. Scape, broadly conical, widest segment, supported ventrally by inverted short "Y-shaped" basal ridge; pedicel oval; segments II to VII or IX long and cylindrical with bulging sides, subequal; terminal segment (fig. B) widest basally tapering to pointed apex. Setae numerous giving antennae bushy appearance; setae absent from scape, 3 to 5 (3.71) short slender setae, 12.4 (7.81-27.2) long, on each pedicel; 3 to 8 (5.19) long fleshy setae on segments III to VIII or IX, each 31.1 (25.4-39.0) long; and always 5 (5.00) long fleshy setae and 1 long terminal knobbed seta, 23.7 (21.5-25.4) long, on each terminal segment; no other knobbed setae observed. Average lengths and widths at broadest area of 9-segmented antennae are as follows:

	I	II	III	IV	V	VI	VII	VIII	IX
Lengths:	20.4	15.1	34.6	29.9	35.1	34.3	30.3	31.3	35.0
Widths:	24.3	18.9	15.5	13.7	14.4	14.8	17.1	15.9	13.5

Spiracles: Submarginal, a pair present on anterior mesothorax (sp_2) and a pair on posterior of metathorax (sp_3), 20.9 (17.3-24.7) long; atrium 9.88 (9.88) wide.

Legs: Three pair of well developed legs with numerous associated long setae on femur, tibia and tarsus. Ratio of legs to entire body length 1:2.3. Coxa (cx): short and broad with 1 to 3 short slender setae, 12.6 (6.83-19.5) long, on distal half of segment. Trochanter (tr): oblong, slightly wider at distal end, a chain of diamond-shaped sensilla encircling basal one-third of segment, trochanter teeth on

antero-ventral surface; 1 very long hairlike seta on distal margin, 16.3 (8.78-19.5) long, and occasionally 1 or 2 shorter setae observed. Femur (fm): robust with extended sides, most setae hairlike, 12.8 (8.78-20.5) long, sometimes with 1 fleshy seta, 3 or 4 on each foreleg, 4 or 5 on each mid- and hindleg. Tibia (tib): long and slender about subequal with femur, a few tibial teeth located ventrally, setae fleshy, 13.3 (11.7-14.6) long, located mainly on distal half, 6 to 8 on each foreleg, 6 to 9 on each midleg and 7 to 10 on each hindleg. Tarsus (tar): cylindrical with bulging sides, one-segmented, a few tarsal teeth ventrally and a single campaniform sensillum (cam. s.) at base. Setae fleshy ($fset_1$) (fig. C) and bifurcated ($fset_2$) (fig. D), 14.9 (12.7-16.6) long, present on entire surface, 8 to 10 on each foreleg, 11 to 15 on each midleg and 15 to 20 on each hindleg. Tarsal digitules (adgt, pdgt) (fig. E) well developed with knobbed tip, always longer than claw and nearly equal on all legs, 21.6 (18.5-25.4) long. Claws (cl) (fig. E): well developed, wide proximally tapering to sharp apex, slightly curved. Ungual digitules (audgt, pudgt) long and slender with knobbed tip which is smaller than tarsal digitule tip, always longer than claw, 17.1 (14.6-19.5) long.

Part of Leg	Lengths Prothoracic	Lengths Mesothoracic	Lengths Metathoracic
Coxa	34.0(24.7-42.0)	33.2(29.6-37.1)	37.9(32.1-44.5)
Trochanter	39.0(32.1-44.5)	41.9(37.1-48.2)	43.4(34.6-49.4)
Femur	59.3(51.9-71.6)	64.0(56.8-76.6)	71.1(56.8-86.5)
Tibia	54.9(54.3-61.8)	66.2(44.5-76.6)	76.0(59.3-81.5)
Tarsus	34.6(22.2-42.0)	45.6(39.5-49.4)	54.6(46.9-64.2)
Claw	15.1(12.4-16.1)	16.1(12.4-19.8)	19.0(14.8-27.2)
Total	211(142-241)	240(179-272)	264(217-297)

Eyes: Two pair well developed. Dorsal simple eyes (dse) oval, 13.7 (11.2-14.8) in diameter, separated by ca. 20.2, submarginally supported by postocular ridge (pocr). Ventral simple eyes (vse) circular, 14.2 (12.4-19.8) in diameter, separated by ca. 17.0, submedially located. Spotlike ocellus (le) faintly sclerotized submarginally on posterior area of gena (g).

Thorax: Oblong, 220 (198-247) long from postoccipital ridge (por) to first abdominal segment and 128 (111-141) wide at mesothorax. Apterous specimens generally membranous with few sclerotized structures; brachypterous and pterygote specimens heavily sclerotized with typical sclerites and ridges (C. americana, plate 7). Prothorax: Membranous, short and wide. Dorsally, without sclerotized structures, pronotal ridge (prn) occasionally distinguished as faint sclerite. Ventrally, several heavily sclerotized ridges present, propleural ridge (plr_1) at coxal base; prosternum (stn_1) well developed, medially. Mesothorax: apterous specimens entirely membranous dorsally and with a few sclerotized structures ventrally; pterygotes with heavily sclerotized dorsum. Dorsally, prescutum (prcs) apical, membranous on apterygotes, slightly sclerotized on pterygotes. Prealare (pra) extending from apex of prescutum (prsc) transversely to body margin encompassing a distinct scutum (sct), on apterygotes rather oblong transversely extending from apex of prescutum to submargin of body then appears to run posteriorly encompassing an indistinct scutum (sct). Scutellum (scl) oblong, heavily sclerotized on winged males, indistinct on wingless specimens, position marked by submedian short tacklike seta on each lateral margin; foramen (sclf) a small membranous area on winged males, not distinguished in wingless

condition. Postalare (pa), posterior, well developed on winged males joining transverse postnotal sclerite (pn_2), with a distinct postnotal apophysis (pna); wingless males, postalare extends as transverse heavily sclerotized structure a short distance from margin of mesothorax and then joins a narrow, weakly developed postnotal sclerite (pn_2); postnotal apophysis not detected. Ventrally, typical structures present on pterygotes and much reduced on apterygotes. Mesosternum (stn_2) membranous, bounded anteriorly by transverse sclerotized ridge which separates prothorax from mesothorax, winged specimens with well developed sclerotized medial ridge (mdr) and an anterior transverse marginal ridge (mr_2); these structures apparently reduced on wingless males. Posteriorly both winged and wingless males with well developed transverse precoxal ridge (pcr_2). Mesofurca (f) prominent winged and wingless conditions joining postalare (pa) at dorso-lateral margin. Pleural ridge (plr_2) distinct on both winged and wingless specimens, submarginally distinctly joins precoxal ridge (pcr_2) on both wing types and joins marginal ridge (mr_2) only on winged specimens and marginally the lateral branches of posterior arm join coxal process (cxp_2), and dorsal arm articulates with postalare (pa). Metathorax: entirely membranous dorsally, small sclerite supporting halters on pterygotes, sclerites absent on apterygotes. Ventrally, metasternum (stn_3) present as weakly sclerotized region, pleural ridge (plr_3) extending to coxal base.

Wings: Possibly three types present; most are apterous (fig. A); one specimen collected indicated brachypterous condition with small veinless oval wings coated with long microtrichica; and several were pterous (fig. F), 505 (489-526) long and 188 (155-229) wide (3 specimens),

with typical venation, one main vein forking anteriorly to radial and posteriorly to medial, neither vein reaching margin; surface covered with microtrichia; wing supported by three small sclerites, ax_1, ax_2 and ax_3, at margin of mesothorax.

Halters: Apterous males without halters; pterygotes with well developed typical halters (fig. G), 33.1 (27.2-39.5) long (5 specimens) with 1 subequal terminal seta recurved at tip.

Abdomen: Slightly fusiform, broad at proximal end, widening somewhat at segment I and II then tapering to narrow genital segment, 195 (153-237) long not including genital segment and 126 (109-136) wide at segment I or II, 8-segmented, entirely membranous except for faint sclerotization at lines of segmentation.

Genital segment: Conical, total segment 241 (211-262) long and 41.2 (32.1-51.9) wide at base, with long pointed stylus (st), 203 (173-210) long, projecting at distal end. Dorsally, small oval anus (an), medially near proximal end with dorsal lip of internal aedeagus (aed) just anterior of anus projecting posteriorly to end of stylus. Internally, basal rod (bra) and penial sheath (pro) prominent. Ventrally, basal ridge of penial sheath (brps) well developed at genital segment base.

MATERIAL STUDIED

Description and measurements were taken from each of the following lots (VPI&SU) collected in Montgomery County, Virginia in 1972 by P. A. Willoughby on Fraxinus americana: 1(3), July 14, PAW052b; 1(3), July 19, PAW056a; 1(8), July 20, PAW054a; 1(2), July 24, PAW057; 1(1), Sept. 21, H14a; 1(2), Sept. 21, PAW095b; 1(1), Sept. 28, H15b; 1(4), Oct. 5, H16a; 2(6), Oct. 12, H17a,b; 1(4), Oct. 19, H18a; 1(2), Oct. 25, H20a.

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VITA

The author was born on January 5, 1947, in Payson, Utah, the eldest daughter of Arlene and Harvey Willoughby. She attended Black Hills Teachers College Elementary School at Spearfish, South Dakota and graduated from Fort Hunt High School at Alexandria, Virginia in 1965. In the fall of that year, she enrolled at Emory and Henry College at Emory, Virginia, where she earned a B. A. degree in 1969 majoring in biology. In November of that year she accepted a biologist position in the pharmaceutical laboratories of A. H. Robins Company, Richmond, Virginia. In January 1972 she enrolled at Virginia Polytechnic Institute and State University to pursue studies leading to a M. S. degree in Entomology.

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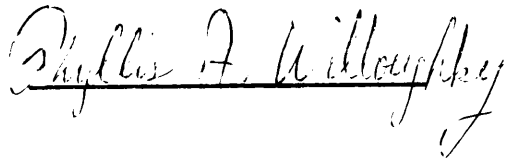

MORPHOLOGICAL AND BIOLOGICAL STUDIES ON TWO SPECIES OF CHIONASPIS (HOMOPTERA: COCCOIDEA: DIASPIDIDAE)

by

Phyllis Ann Willoughby

(ABSTRACT)

Morphological studies in the past have been almost exclusively confined to the description and illustration of adult females. Morphological studies of Diaspididae were further restricted to the pygidial area. This study is an attempt to provide complete descriptions, illustrations and measurements for morphological characters for all life stages of C. americana Johnson and C. kosztarabi Takagi and Kawai.

The majority of the specimens were obtained from weekly collections of local infestation on the Virginia Polytechnic Institute and State University campus. Freshly collected scale insect samples were mounted in both Hoyer's medium and Canada balsam for microscopic study.

The biologies of the two species in Blacksburg, Virginia were studied using weekly collections. Both species were bivoltine. C. americana overwintered mainly in the egg stage; the first brood hatched about April 20, and the second brood about July 25, in 1972. C. kosztarabi overwintered as fertilized females. Eggs were laid in early spring hatching about May 28 in 1973, and the eggs of the second generation began hatching about August 10, in 1972. Dimorphic males of both species were collected. C. americana males exhibited apterous and brachypterous conditions. C. kosztarabi males were either apterous or pterous. Several species of hymenopterous parasites were reared from each species.