The Great Lakes Entomologist

Volume 19
Number 4 - Winter 1986 *Number 4 - Winter 1986*

Article 6

December 1986

Life History and Laboratory Rearing of *Corythucha Juglandis* (Hemiptera: Tingidae) With Descriptions of Immature Stages

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LIFE HISTORY AND LABORATORY REARING OF *CORYTHUCHA JUGLANDIS* (HEMIPTERA: TINGIDAE) WITH DESCRIPTIONS OF IMMATURE STAGES[1]

T. E. Vogt and J. E. McPherson[2]

ABSTRACT

The life history of *Corythucha juglandis* was investigated in Jackson and Alexander counties, Illinois, August 1981–December 1985 and the immature stages were described. The bug was also raised from egg to adult under controlled laboratory conditions. This apparently bivoltine species overwintered as adults that became active in late April-early May, began feeding on the undersides of black walnut leaflets, and reproduced shortly thereafter. The seasonal occurrence of the adults and subsequent immature stages is discussed. Adults were last observed in mid-October. *C. juglandis* was reared on black walnut leaflets under a 16L:8D photoperiod at ca. 23.9°C. The pre-ovipositional, ovipositional, and post-ovipositional periods averaged 14.0, 50.3, and 11.9 days, respectively; average fecundity was 118.6. The incubation period, and 1st, 2nd, 3rd, 4th, and 5th stadia averaged 16.4, 4.3, 3.8, 4.2, 4.6, and 6.7 days, respectively.

The phytophagous family Tingidae (lace bugs) is cosmopolitan and contains three subfamilies, 236 genera, and 1820 species (Drake and Ruhoff 1965). The genus *Corythucha* Stål is restricted to the Western Hemisphere and 48 of its 68 species have been reported from the United States (Bailey 1951, Drake and Ruhoff 1965). Many of the *Corythucha* species are strikingly similar to each other (Bailey 1951).

Most members of this family feed on the undersides of leaves and are gregarious (Bailey 1951, Drake and Ruhoff 1965). Several are noted pests of trees, extracting photosynthates from the leaves (Baker 1972). In heavy infestations, the upper leaf surfaces either whiten or turn brown (Baker 1972).

Corythucha juglandis (Fitch) ranges from New England north to New Brunswick, west and southwest to Kansas and Texas, and south to North and South Carolina and Georgia (Drake and Ruhoff 1965). It is common in New England (Bailey 1951), Ohio, Indiana, and Illinois (as *C. contracta* Osborn and Drake by Drake [1921], see Drake and Ruhoff [1965]). Although this tingid has been listed from several plants, it has been most frequently reported from black walnut (*Juglans nigra* L.), butternut (*J. cinerea* L.), pecan (*Carya illinoensis* (Wangenheim)), and linden or basswood (*Tilia* sp.) (as *C. contracta* by Drake [1921], as *C. contracta* and *C. juglandis* by Blatchley [1926], see Drake and Ruhoff [1965], Bailey [1951] and Sheeley and Yonke [1977]). Sheeley and Yonke (1977) suggested, however, that hosts other than *Juglans* spp. are incidental. When they found *C. juglandis* on a questionable host, there was usually a walnut tree in the immediate vicinity and the questionable host had few, if any, feeding or excrement spots.

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[1]Part of a thesis submitted to Southern Illinois University at Carbondale by the senior author in partial fulfillment of the requirements of the M.S. degree in Zoology.

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C. juglandis is apparently trivoltine in Missouri (Sheeley and Yonke 1977) and bivoltine in New Jersey (as *C. parshleyi* Gibson by Weiss and Dickerson [1918], as *C. contracta* by Barber and Weiss [1922], see Drake and Ruhoff [1965]). In Missouri, overwintered adults appear in late April-early May and egg laying begins by late May (Sheeley and Yonke 1977). First generation adults appear in late June-early July, second generation adults in late July-early August, and third generation adults in late August-early September; these last adults overwinter. In New Jersey, overwintered adults appear in mid-May and egg laying begins by late May (Weiss and Dickerson 1918, Barber and Weiss 1922). First generation adults appear in early July and second generation adults by late August; these last adults overwinter.

C. juglandis usually lays its eggs singly on the ventral side of the leaflet at the juncture of the midrib and secondary veins (Weiss and Dickerson 1918, Barber and Weiss 1922, Bailey 1951, Sheeley and Yonke 1977) and usually on the basal half of the leaflet (Weiss and Dickerson 1918, Barber and Weiss 1922, Bailey 1951).

Leaves upon which *C. juglandis* has been feeding, if severely attacked, become yellow and dry, frequently falling to the ground (Weiss and Dickerson 1918, Barber and Weiss 1922, Sheeley and Yonke 1977). Bailey (1964) suggested that a stunted butternut observed during his study may have resulted, in part, from a heavy infestation of this tingid.

The eggs (Weiss and Dickerson 1918, Bailey 1951) and nymphs (Weiss and Dickerson 1918) have been briefly described, but not illustrated. Also, some brief notes have been published on rearing of this tingid on black walnut (Sheeley and Yonke 1977) and a "suitable host plant" (Horn et al. 1979).

This study presents further information on field life history and laboratory rearing of *C. juglandis*, and includes detailed descriptions and illustrations of the immature stages.

MATERIALS AND METHODS

Life History

Several *C. juglandis* adults were found at a black walnut plantation near Tamms in Alexander County, Illinios, during August 1981 and on three black walnut trees near the USDA Forestry Sciences Laboratory on the Southern Illinois University at Carbondale (SIUC) campus during May 1982. Preliminary data collected during the active season of 1982 at both sites suggested a detailed life history study was possible. Thus, a study of these populations was conducted from fall 1982 into fall 1985. Most data were collected during 1983 and 1984 from late April to mid-October, before the bugs emerged from and after they entered overwintering sites, respectively. Leaf litter samples were collected at the Tamms site November and December 1982 and the SIUC site December 1985 and examined for overwintering individuals.

Counts of adults and nymphs and notes on their activity were taken 1–3 times/week at the SIUC site and weekly at the Tamms site. Counts consisted of two types: (1) number of adults observed from ground level in 5 minutes, and (2) number and instars of all nymphs observed from ground level with no time limitations. Eggs were inspected and instars distinguished with the aid of a 5X magnifying glass. Eggs were simply noted as present or absent because of difficulty in distinguishing between fertile and infertile eggs. However to serve as a check for field identification of instars, particularly 1sts–3rds which appear very similar, small samples were occasionally collected and compared with laboratory-reared specimens.

Sheeley and Yonke (1977) reported marked overlapping of generations during the active season for *C. juglandis*. Therefore, a sleeve cage was used at the SIUC site to isolate a small group of individuals (10–15) to help determine generation time. The cage was cylindrical with a hole at each end through which a supporting branch was passed. This cage, modified from Cuda and McPherson (1976), consisted of two half-cylinders held together with Velcro®. The frame of each half was constructed of three 60-cm pine

wood strips (1/2 x 3/4") and two semicircular end pieces (1/8" wall paneling, 30 cm along straight edge). Each end piece was attached at each corner to the end of a strip (lateral) and at the midpoint of the arc to the third strip (median) with two nails/strip at each end. A piece of acetate, to permit observations of the lace bugs and provide protection from rain, was stapled to the strips and end pieces of the upper half, and Lumite Saran® (32 x 32 mesh), for ventilation, to the lower half. Velcro® was glued and stapled to the opposable faces of the lateral strips of both half-cylinders and a thin strip of foam rubber glued to the opposable face of each end piece of the upper half to permit a tight seal. The cage was supported with wire wrapped around higher branches and passed through a screw eyelet fastened to the upper median strip at each end.

Four 4th and eight 5th instars were placed in the cage on 22 June 1984 after inspection of the leaflets with the magnifying glass to insure the absence of tingids (including eggs). Adults emerged on 3 July and reproduced shortly thereafter. The cage was moved to fresh leaflets on 30 July, again after inspection to insure absence of tingids, and 3 3rd, 17 4th, and 47 5th instars from the offspring of the caged previous generation were added.

A censusing of *C. juglandis* adults and nymphs was conducted for a single, heavily infested, black walnut tree at the SIUC site on 28–29 August 1984 to help determine spatial distribution of this lace bug. The tree was ca. 12 m in height with a diameter at breast height (DBH) of 21 cm. A ladder was used to reach higher leaflets for close inspection to determine numbers and stages present. Eye level from the top of the ladder was 10 m and no tingids were observed above this height. Heights above ground of all adults and nymphal instars were measured to the nearest 5 cm and then lumped into 1-meter intervals. Distribution of these same bugs on the crown's estimated leafed inner and outer halves was also recorded.

Laboratory Rearing

Twenty overwintering adults (10 males, 10 females) were collected at the SIUC site on 19 May 1983, taken to the laboratory, and placed in petri dishes (ca. 9 cm diam., 2 cm depth) (1 male, 1 female/dish). Each dish was covered on the bottom with a disc of filter paper; the paper was moistened daily with distilled water and any condensation wiped from the lid. Two black walnut leaflets were added to serve as food and as oviposition sites. Preliminary data indicated that females preferred to oviposit while upside down on the ventral side of the leaflet. To provide this opportunity, but to increase the female's choices, the first leaflet was placed on the paper ventral side up and the second placed over it ventral side down, but touching only at the base and apex, leaving a gap between the two. The paper and leaflets were replaced every 2–3 and 1–3 days, respectively.

Leaflets were examined daily for eggs. Those with eggs were removed and placed in separate petri dishes on filter paper, always with the eggs upward. The paper was moistened and condensation wiped from the lids daily. A fresh leaflet, placed ventral side up, was added 12 days later in anticipation of hatching (ca. 15 days, based on preliminary incubation data) and the dish was covered with plastic and closed with the lid to prevent the escape of recently hatched nymphs. Orienting the leaf ventral side up permitted the nymphs to be easily observed while it exposed them to their preferred feeding surface and helped prevent them from drowning in the moist paper.

Nymphs hatching on the same day were kept together in groups of up to 10 and reared to adults on single leaflets, placed ventral side up, in petri dishes prepared similarly to those used for adults and eggs. These dishes were also covered with plastic and closed with the lids to prevent the 1st instars from escaping; however, the plastic was removed for later instars because escape was not a problem and the plastic increased condensation. Exuviae were counted and removed daily. Filter paper was moistened daily and condensation wiped from the lids and plastic. Leaflets were replaced every 2–3 days.

Cultures were kept in incubators maintained at ca. 23.9 ± 1.1°C and a 16L:8D photoperiod (ca. 260 ft-c).

Thirty 1st generation 5th instars were collected at the SIUC site on 26 June 1984, returned to the laboratory, and placed in petri dishes (7-8/dish). Upon reaching adults, seven males and seven females were selected and also placed in petri dishes (1 male, 1 female/dish). Dishes for 5ths and adults were prepared similarly to those of the same stage in the rearing study. Leaflets in the seven dishes were examined daily for eggs to determine the pre-ovipositional, ovipositional, and post-ovipositional periods; and fecundity.

Descriptions of Immature Stages

Eggs and 1st-5th instars were collected at the SIUC site and preserved in 75% ethanol. The description of each stage is based on 10 individuals. Drawings were made with the aid of SEM photomicrographs, measurements with an ocular micrometer. Dimensions are expressed in mm as $\bar{x} \pm SE$. SE values < 0.005 (rounded to the nearest hundredth) are listed as 0.00.

RESULTS AND DISCUSSION

Life History

Data from the Tamms site during 1983 and 1984 were limited because of a marked decrease in the population; therefore, discussion applies only to the SIUC site unless stated otherwise.

Adults generally emerged from overwintering sites in early May (one individual was observed 23 April 1982), began feeding on the underside of black walnut leaflets, and reproduced shortly thereafter. The mating position was end-to-end and at an approximate right angle as reported by Sheeley and Yonke (1977).

Eggs were found from the third week of May to mid-August (Figs. 1A-B). They were generally laid singly, occasionally in clusters of 2–4, on the undersides of leaflets at the juncture of the midrib and secondary veins, and usually on the basal half of the leaflet. These observations support those of Weiss and Dickerson (1918), Barber and Weiss (1922), Bailey (1951), and Sheeley and Yonke (1977).

The 1st instars were found from early June to late August, 2nd and 3rd instars from mid-June to late August, 4th instars from the third week of June to early September, and 5th instars from the third week of June to the third week of July and from mid-August to early September (Figs. 1A-B). Nymphs were gregarious and, as with adults, occurred on the undersides of leaflets.

The leaflets began to yellow in early July and continued to deteriorate for the rest of the season. Nearly all had fallen at both sites by mid-September. This apparently was due to some factor other than tingid feeding, possibly a fungus, *Mycosphaerella juglandis* Kessler (Weber, pers. comm.). Leaflets with tingids were characterized by excrement spots, exuviae, and whitening of the upper surfaces.

Most adults began to leave the trees by mid-September, although a few individuals were found on leaflets during mid-October at the Tamms site. All leaf litter samples, when placed in Berlese funnels, yielded several adults and indicated that litter is an important overwintering site. No individuals were found overwintering beneath bark.

C. juglandis is apparently bivoltine in southern Illinois. Although there was marked overlapping of the various stages and, thus, any particular sample could have any combination of individuals (Fig. 1A), weekly plotting of data for adults and each nymphal instar generally showed two peaks of abundance (Fig. 1B). First generation adults appeared in late June as was evidenced by the presence of teneral individuals. Also, teneral adults were first observed in the sleeve cage on 3 July. Second generation (overwintering) adults appeared in early August as was evidenced by the appearance of

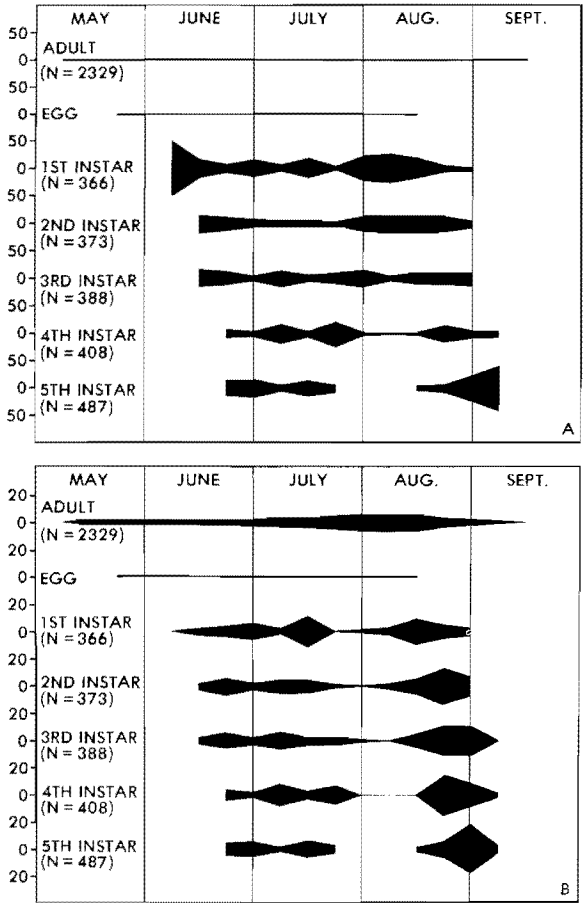

Fig. 1. (A) Percent of individuals in each instar per sample collected at the SIUC campus, Jackson County, Illinois, during 1983–1984 (eggs and adults not included, see text). (B) Percent in each sample of total individuals of same instar collected at the SIUC campus, Jackson County, Illinois, during 1983–1984 (eggs not included, see text).

adults on 4 August in the sleeve cage containing second generation nymphs. These adults failed to reproduce, and were removed from the cage during the third week of September after no other tingids were observed on the trees.

On the single tree censused, most individuals were observed from 1 to 7 m above ground (94.0%) and on the crown's leafed outer half (89.3%) (Fig. 2).

Laboratory Rearing

The pre-ovipositional, ovipositional, and post-ovipositional periods averaged 14.0, 50.3, and 11.9 days, respectively; fecundity averaged 118.6 (Table 1).

Table 1. Pre-ovipositional, ovipositional, and post-ovipositional periods (in days), and fecundity of *C. juglandis* under laboratory conditions[a,b].

	Range	$\bar{x} \pm SE$
Fecundity	96–166	118.6 ± 8.4
Pre-ovipositional	12–18	14.0 ± 0.8
Ovipositional	43–63	50.3 ± 2.4
Post-ovipositional	7–18	11.9 ± 1.4

[a]Based on seven females.
[b]830 eggs were laid.

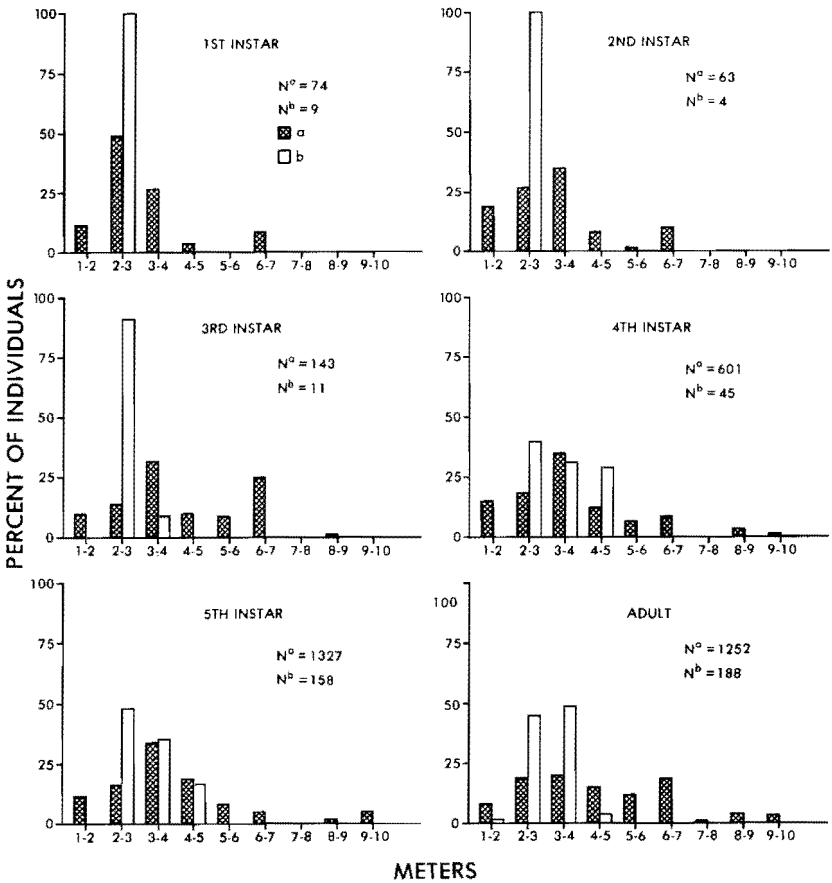

Fig. 2. Spatial distribution of *C. juglandis* on a heavily infested black walnut tree on SIUC campus, Jackson County, Illinois, during 28–29 August 1984: (a) crown's estimated outer half, (b) inner half.

Eggs were generally laid singly, occasionally in clusters of 2–4. Of the 1072 deposited (1983, 1984) 98.6% were laid on the upper leaflet, with the remaining 1.4% on the lower. All were laid on the ventral surface at the juncture of the midrib and secondary veins and usually on the basal half of the leaflet. None was laid on dorsal leaf surfaces, filter paper, or dishes. The incubation period averaged 16.4 days (Table 2).

The 1st instar emerged through an operculum at the cephalic end. It was pale at this time with red ommatidia and translucent legs, but darkened to its normal color in 1.5 hr (see description).

The 1st, 2nd, 3rd, 4th, and 5th stadia averaged 4.3, 3.8, 4.2, 4.6, and 6.7 days, respectively; total developmental period averaged 40.0 days (Table 2).

Most nymphal mortality resulted from drowning in water condensation on the lid and plastic. Also, incomplete ecdysis was occasionally observed.

Descriptions of Immature Stages

Egg (Figs. 3, 4A). Length, 0.54 ± 0.01; width, 0.18 ± 0.00. Eggs generally laid singly, occasionally in clusters of 2–4. Color dark brown to black apically, translucent basally; areas separated by diffuse subcrescentic border. Shape elongate, slightly curved, broadest at basal 1/3, narrowing anteriorly and terminating with conical operculum set off from remainder of egg by constriction. Operculum comprised of three regions: basal 1/3 with smooth collar; middle 1/3 and apical 1/3 with small and large areolae, respectively. Chorion smooth except apical 2/3 of operculum.

Nymphal Instars. The 1st instar is described in detail, but only major changes that have occurred from previous instars are described for subsequent instars. Length is measured from anterior margin of head to tip of abdomen; width across widest part of the body, usually abdominal segments 3–4. Additional measurements are presented in Table 3. Body armature (Fig. 4B) is divided into two categories: seta, defined here as an elongate bristle; and chalaza, as a seta arising from a prominent conical base. Measurements exclude these structures.

First Instar (Figs. 4C-D). Length, 0.60 ± 0.01; width, 0.24 ± 0.00. Body elongate elliptical; dorsally, medial 2/3 of thorax and particularly abdomen elevated; ventrally, thorax flattened, abdomen convex. Sclerotized areas of body light brown to brown; integument smooth. Color dorsally light brown with broad medial mark extending over meso- and metathoraces and abdominal segments 1–2 yellowish white; dorsolaterally and ventrally yellow to yellowish white, laterally brown.

Table 2. Duration (in days) of each immature stage of *C. juglandis* under controlled laboratory conditions.

Stage	Number completing stadium	Range	$\bar{x}$ ± SE	Cumulative mean age
Egg	187[a]	15–21	16.4 ± 0.1	16.4
Nymph				
1st instar	136	2–8	4.3 ± 0.1	20.7
2nd instar	121	2–8	3.8 ± 0.1	24.5
3rd instar	101	2–8	4.2 ± 0.1	28.7
4th instar	96	3–10	4.6 ± 0.1	32.3
5th instar	90	5–12	6.7 ± 0.1	40.0

[a]242 eggs were laid.

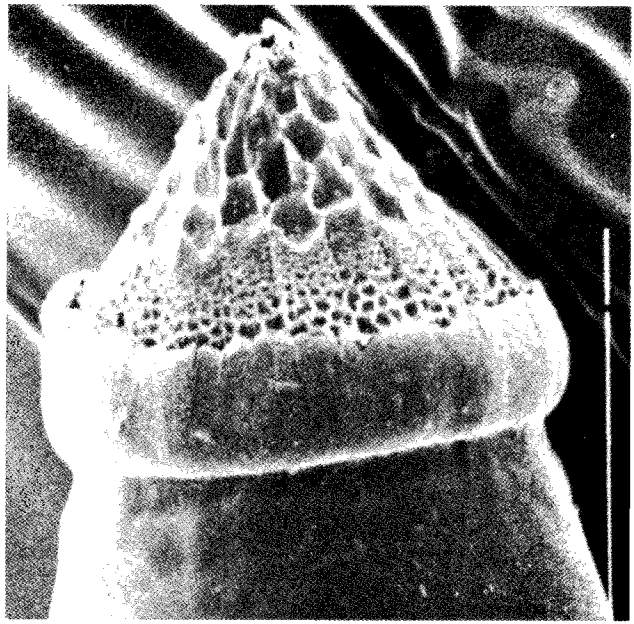

Fig. 3. SEM photomicrograph of operculum of *C. juglandis* egg. Gap in magnification index line = 1 micron.

Head markedly declivent anterior to compound eyes; tylus exceeding and elevated above juga; compound eye with five widely spaced red ommatidia; synthlipsis ca. 5/6 width of head. Head light brown to brown; tylus and apices of juga yellowish white; pale arcuate line extending medially from inner margin of each eye to midline of vertex and then straight back across pronotum, fading posteriorly on remainder of thorax or on abdomen. Three pairs of chalazae present, one pair at base of tylus each side of midline, one pair medially on frontal disc, and one pair on vertex; those on frons and vertex arising from common elevated bases; one seta present on elevated base posterior to each vertex chalaza. Antennae yellowish white, 3-segmented; with scattered, well developed setae; cluster of short setae at apex; ratio of segments ca. 3:3:11. Beak yellowish white, 4-segmented, extending onto abdomen.

Nota each with well developed medial plate, laterally membranous; plate of pronotum brownish, plates of meso- and metanota brownish with medial yellowish white mark. pronotum subtrapezoidal, ca. 1/3 long as wide along midline; anterior margin almost straight; posterior margin slightly arcuate each side of midline, bending cephalad laterally; each lateral margin with one chalaza. Mesonotum ca. 1/2 length of pronotum along midline, subequal along lateral margin; posterior margin similar to that of pronotum; one chalaza present medially each side of midline and along lateral margin. Metanotum ca. 4/5 length of mesonotum along midline; posterior margin similar to that of mesonotum; well developed chalazae absent. Thoracic pleural areas sclerotized and brownish; spiracle present dorsally near bases of legs between pro- and mesopleura and meso- and metapleura. All coxae yellowish brown, remaining segments yellowish white; tarsi 2-segmented, segment 1 short, ca. 1/3 as long as 2; the two claws brownish yellow.

Abdomen dorsally with scent glands opening medially between segments 3–4 and 4–5; segments 2–9 with one chalaza posteriorly on lateral margin; segments 2, 5, 6, and 8 with

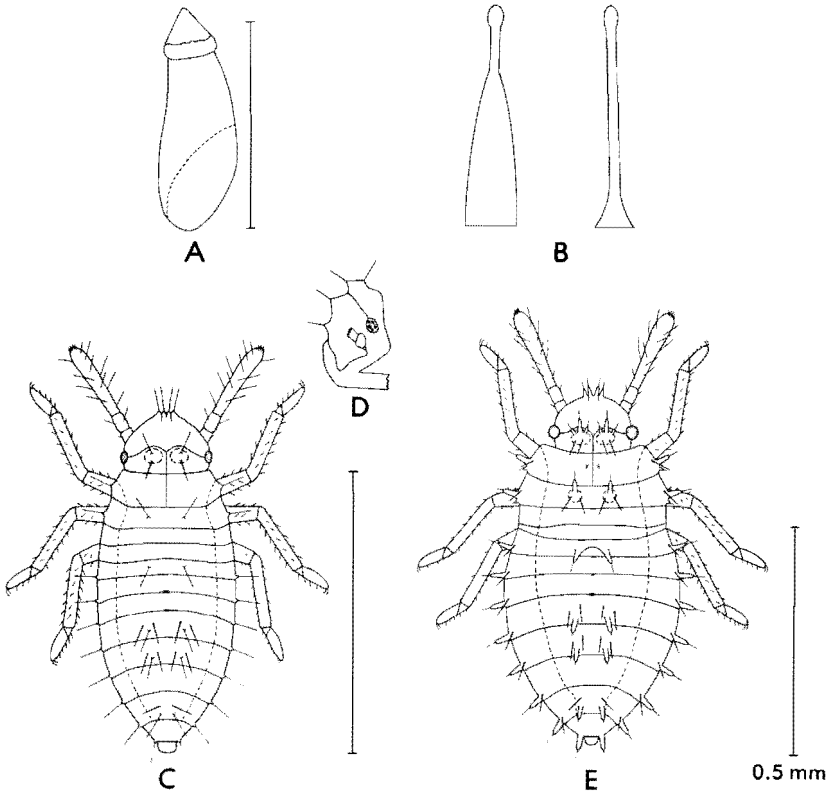

Fig. 4. Immature stages and body armature of *C. juglandis*: (A) egg, (B) chalaza (left) and seta (right) of 3rd instar, (C) 1st instar, (D) 1st instar (lateral view of head) (E) 2nd instar.

Table 3. Measurements (mm)[a,b,c] of *C. juglandis* instars.

	Nymph				
	1st instar	2nd instar	3rd instar	4th instar	5th instar
Body length	0.60 ± 0.01	0.78 ± 0.01	1.18 ± 0.00	1.71 ± 0.02	2.10 ± 0.04
Body width	0.24 ± 0.00	0.36 ± 0.01	0.55 ± 0.01	0.79 ± 0.01	1.20 ± 0.01
Width at eyes	0.17 ± 0.00	0.22 ± 0.01	0.29 ± 0.00	0.36 ± 0.00	0.46 ± 0.01
Synthlipsis	0.14 ± 0.00	0.17 ± 0.00	0.21 ± 0.00	0.26 ± 0.00	0.32 ± 0.01
Head length[d]	0.13 ± 0.00	0.15 ± 0.00	0.19 ± 0.01	0.21 ± 0.01	0.28 ± 0.01
Antennal length	0.22 ± 0.00	0.32 ± 0.01	0.44 ± 0.01	0.64 ± 0.01	0.99 ± 0.01
Labial length	0.33 ± 0.01	0.36 ± 0.01	0.47 ± 0.00	0.58 ± 0.01	0.69 ± 0.02
Pronotal length[d]	0.06 ± 0.00	0.08 ± 0.00	0.13 ± 0.00	0.24 ± 0.00	0.65 ± 0.01
Pronotal width	0.20 ± 0.00	0.30 ± 0.01	0.46 ± 0.00	0.66 ± 0.00	1.04 ± 0.01

[a]$\bar{x}$ ± SE.
[b]SE values < 0.005 listed as 0.00.
[c]N = 10.
[d]Measured along midline.

one chalaza present medially each side of midline; segments 5 and 6 with two setae, segment 8 with one seta, each side of midline, all setae per segment arising with respective chalazae from common base that is elevated above remainder of dorsum. Segments 2–8 with pair of spiracles ventrolaterally, each spiracle located at dorsolateral margin of lateral sclerite.

Second Instar (Fig. 4E). Length, 0.78 ± 0.01; width, 0.36 ± 0.01. Body less elongate; dorsally, medial 1/2 of abdomen elevated; surface of body dorsally, and of pleura, covered with spinules. Color brown dorsally with medial mark of meso- and metathoraces and abdominal segments 1–2 yellowish white; thorax dorsolaterally and ventrally yellowish white, laterally brown; abdomen laterally brown, ventrally brown with median yellowish white strip that tapers posteriorly. Bases of chalazae proportionately larger than in 1st instar.

Synthlipsis ca. 7/10 width of head. Head brown, color of tylus and juga similar to those of 1st instar. Chalazae and setae in same positions as in 1st instar; vertex with cluster consisting of three chalazae anteriorly and two setae posteriorly each side of midline. Ratio of antennal segments ca. 6:5:22.

Pronotum ca. 1/4 long as wide along midline; anterior margin concave; posterior margin convex; one chalaza anteromedially each side of midline and cluster of two chalazae and one seta on each posterolateral corner. Mesonotum ca. 2/3 length of pronotum along midline; posterior margin nearly straight; cluster of one chalaza and two setae present medially each side of midline on raised discs; posterolateral cluster of chalazae and setae present and resembling those of pronotum. Metanotum ca. 2/3 length of mesonotum along midline; posterior margin similar to that of 1st instar.

Abdomen dorsally with segment 1 constricted laterally; segments 2–8 with one seta dorsally near posterolateral margin adjacent to posterolateral chalaza; medial chalazae of segment 2 joined basally by narrow transverse ridge. Segments 2–8 with pair of spiracles ventrolaterally, each spiracle centrally located within lateral sclerite that is fused to ventral sclerite, these ventral sclerites separated medially by yellowish white membranous strip that tapers posteriorly.

Third Instar (Fig. 5A). Length, 1.18 ± 0.00; width, 0.55 ± 0.01. Body less elongate. Color dorsally dark brown with yellowish white medial and lateral marks; medial mark extending over meso- and metathoraces and abdominal segments 1–2, each lateral mark extending over abdominal segments 1–3, medial and lateral marks separated by dark brown strip; thorax laterally dark brown, ventrally yellowish white; abdomen laterally dark brown, ventrally dark brown with median yellowish white strip that tapers posteriorly. Bases of chalazae proportionately larger than in previous instars.

Compound eye with ca. 7–8 red ommatidia. Head dark brown, color of tylus and juga similar to those of previous instars. Chalazae and setae in same positions as in previous instars; frontal disc with cluster of 3–4 chalazae; vertex with cluster of three chalazae and three setae each side of midline. Antennae 4- segmented, ratio of segments ca. 3:3:10:7.

Nota with well developed medial and lateral plates, lateral plates of pro- and mesonota partially fused to respective medial plates and completely fused to respective pleura, lateral plates of metanotum not fused to medial plate but fused to pleuron; medial plate of pronotum dark brown, those of meso- and metanota dark brown with medial yellowish white marking; lateral plates of nota dark brown, membranous areas yellowish white. Pronotum ca. 1/3 long as wide along midline; posterior margin medially extending more posteriorly; three pairs of chalazae present medially each side of midline, two pairs anteromedially with bases contiguous, and one pair posteromedially; cluster of three chalazae of unequal size (smallest not visible in dorsal view) and one seta at posterolateral corner; and single chalaza on lateral margin, usually midway between antero- and posterolateral corners. Mesonotum ca. 1/2 length of pronotum along midline; medial chalazae in same positions as those of previous instar, lateral chalazae and posterolateral clusters similar to those of pronotum; wing pads weakly evident. Metanotum with posterior margin straight.

Abdomen dorsally with segment 1 constricted laterally, not reaching lateral margin of body; segments 2–3 with one chalaza; 4–9 with pair of chalazae of unequal size (smallest

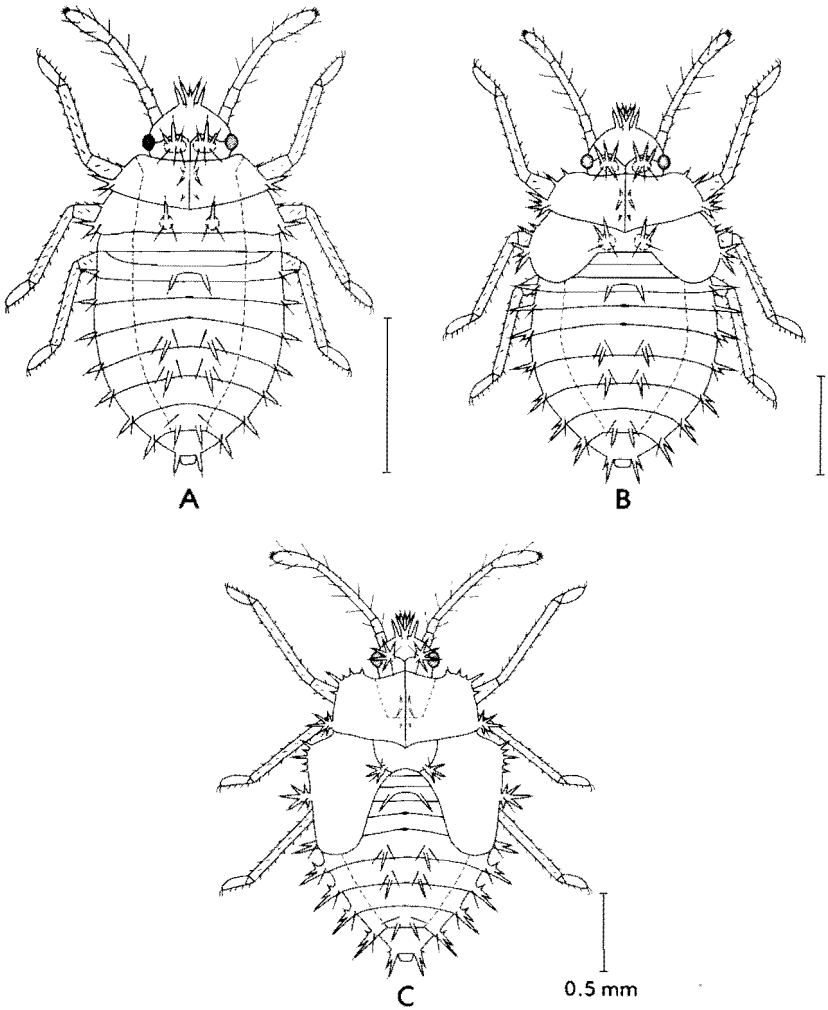

Fig. 5. Immature stages of *C. juglandis*: (A) 3rd instar, (B) 4th instar, (C) 5th instar.

not visible in dorsal view); and 2–8 with one seta; chalazae and setae located at posterolateral corners of respective segments.

Fourth Instar (Fig. 5B). Length, 1.71 ± 0.02; width, 0.79 ± 0.01. Body dorsally with medial 2/3 of both pronotum and abdomen elevated, medial areas of meso- and metanota not elevated. Color dorsally dark brown with medial and lateral (4) marks yellowish white; medial mark subtriangular, extending and narrowing from abdominal segment 2 to posterior area of pronotum; lateral marks paired, each member of anterior pair at posterolateral corner of pronotum, each member of posterior pair extending over abdominal segments 1–3; medial and lateral abdominal marks separated by dark brown mark. Bases of chalazae proportionately larger than in previous instars.

Compound eye with ca. 28 red ommatidia. Chalazae and setae in same positions as in previous instars; frontal disc with cluster of 4–7 chalazae; vertex with cluster of 3–5 chalazae and 1–2 setae each side of midline. Ratio of antennal segments ca. 5:4:16:12.

Nota with well developed medial and lateral plates, lateral plates completely fused to respective medial plates and pleura, general areas of fusion per segment marked with longitudinal yellowish streak. Pronotum with anterior margin slightly triarcuate; posterior margin medially extending more posteriorly than in previous instar; cluster of four chalazae and one seta at posterolateral corner; and two chalazae on lateral margin anterior to posterolateral cluster. Mesonotum ca. 1/3 length of pronotum along midline; wing pads extending onto abdominal segment 2; cluster of two chalazae and two setae present medially each side of midline; cluster of chalazae and seta present on lateral margin posteriorly, similar to those on posterolateral corner of pronotum, and preceded by two chalazae between cluster and pronotum. Metanotal wing pads small, covered by those of mesonotum.

Pattern of chalazae on abdominal segments 2–3 as in previous instar; segments 4–9 with three chalazae of unequal size (smallest not visible in dorsal view); segments 2–8 with one seta as in previous instar.

Fifth Instar (Fig. 5C). Length, 2.10 ± 0.04; width, 1.20 ± 0.01. Body dorsally with medial 1/3 of pronotum and 3/4 of abdomen elevated, medial areas of meso- and metanota not elevated. Color dorsally and ventrally dark brown with much of medial and lateral marks yellowish; dorsally, medial mark extending from abdominal segment 3 to anterior margin of pronotum and consisting of two parts, a posterior hourglass shape and an anterior mediolongitudinal strip. Pronotum with lateral margins yellowish, encompassing dark brown spot. Mesonotum (including wing pads) yellowish with dark brown area each side of midline, wing pads with posterior and inner margins dark brown. Metanotum with exposed region yellowish. Bases of chalazae proportionately larger than in previous instars.

Compound eye with ca. 50 red ommatidia. Chalazae and setae in same positions as in previous instars; frontal disc with cluster of 4–6 chalazae; vertex with cluster of 5–7 chalazae and 1–3 setae each side of midline. Ratio of antennal segments ca. 7:5:23:14.

Pro- and mesonota with lateral margins explanate. Pronotum markedly tumid anteromedially, carinate posteriorly, carina running from posterior area of segment to base of tumid area; ca. 3/5 long as wide; anterior margin triarcuate; posterior margin medially extending more posteriorly than in previous instar; cluster of 4–5 chalazae and one seta at posterolateral corner; and 3–7 chalazae on lateral margin anterior to posterolateral cluster. Mesonotum ca. 1/4 length of pronotum along midline; posterior margin arcuate medially; wing pads extending onto abdominal segment 5; cluster of 2–3 chalazae and 1–2 setae present medially each side of midline; cluster of chalazae and seta present near mid-lateral margin of wing pads, similar to those on posterolateral corner of pronotum, and preceded by 3–6 chalazae on lateral margin between cluster and pronotum. Metanotum ca. 1/3 length of mesonotum along midline; wing pads extending onto abdominal segment 5, covered by and slightly shorter than those of mesonotum.

Chalazae and setae absent on segments 2–3; three chalazae present on segments 4–9 (smallest now visible in dorsal view), and one seta on segments 4–8.

ACKNOWLEDGMENTS

We thank Drs. J. A. Beatty and W. G. Dyer, Department of Zoology, Southern Illinois University at Carbondale, for their critical reviews of the manuscript; Dr. L. C. Matten, Department of Botany, for his assistance with SEM photomicrographs; and Ms. Cindy Clabought and Ms. Karen Schmitt, Scientific Photography and Illustration Facility, for the final illustrations of the immature stages. We are also grateful to Dr. Barbara C. Weber, USDA Forest Service, North Central Forest Experiment Station, Forestry Sciences Laboratory, for her assistance in the field. This research was partially funded by the USDA Forest Service (Cooperative Research Agreement No. 23-81-28).

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