Zootaxa 2357: 50–62 (2010)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

The adult male and male nymphal instars of *Ceroplastes rusci* (Linnaeus) (Hemiptera: Coccoidea: Coccidae)

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Abstract

The morphology of the adult male and male nymphal instars of *C. rusci* are described and illustrated. A key to the adult males of the described *Ceroplastes* and *Waxiella* male species (*Ceroplastes ceriferus* (Fabricius), *C. cirripediformis* Comstock, *C. japonicus* Green, *Waxiella berliniae* (Hall) and *Waxiella* sp.) is provided and their taxonomic affinities discussed.

Key words: *Ceroplastinae*, *Ceroplastes cirripediformis*, *C. ceriferus*, *C. japonicus*, *Waxiella berliniae*, *Waxiella* sp., wax scales

Introduction

The classification of the scale insects (superfamily Coccoidea) is based almost entirely on adult female structure, whilst the morphology of the adult male and nymphal stages of most Coccoidea are poorly known. Whilst a few adult males and other stages had been described prior to the 1960s, it was only then that the first really detailed descriptions of several adult males appeared (Theron, 1958; Ghauri, 1962; Giliomee, 1967; Afifi, 1968). The adult males, unlike neotenic females, are fully mature insects and their large number of morphological characters can therefore be used to show relationships, particularly at the family and subfamily levels (Boratynski, 1971; Hodgson, 2001; Hodgson & Henderson, 2004; Hodgson & Foldi, 2006).

Ceroplastes is a very large genus placed in the subfamily Ceroplastinae or wax scales. From this genus, several controversial genera have been split, most of them presently regarded as synonyms (Hodgson, 1994). Some authors (Gimpel *et al*., 1974; Ben-Dov, 1993) recognized only *Ceroplastes*, *Vinsonia* and *Waxiella* as separate genera. Qin & Gullan (1995), after a cladistic analysis, concluded that the group is monophyletic and all the wax scales should be classified into the genus *Ceroplastes*. The genus *Vinsonia* was recently synonymized with *Ceroplastes* (Peronti *et al*., 2008), so that, at present, the subfamily Ceroplastinae only includes two genera: *Ceroplastes*, with 135 species, and *Waxiella*, with 20 species (Ben-Dov *et al*., 2009). The *Ceroplastes* species have a worldwide distribution (much of this perhaps due to human activity) whereas the species presently included in *Waxiella* are distributed mainly in Africa.

Despite the large number of species in the Ceroplastinae, the adult males of only 5 species have been well described, namely *Ceroplastes ceriferus* (Fabricius), *C. cirripediformis* Comstock, *C. japonicus* Green (Gimpel *et al*., 1974; Rainato & Pellizzari, 2008), *Waxiella berliniae* (Hall) and *Waxiella* sp., (previously described as *Ceroplastes* species) (Giliomee, 1967).

C. rusci was the first wax scale to be described (Linnaeus, 1758) and is mainly known from the countries surrounding the Mediterranean basin and in Africa. Despite its wide distribution and pest status in many countries, only the adult female is known in detail (Hodgson, 1994; Pellizzari & Camporese, 1994). The adult male and both male and female nymphal instars have been described long ago (Silvestri & Martelli, 1908; Khasawinah & Talhouk, 1964), but these descriptions are inadequate by present day standards. This paper

 Accepted by C. Hodgson: 31 Dec. 2009; published: 11 Feb. 2010

provides detailed descriptions of the adult male and male instars of *C. rusci* and compares them with recent descriptions of the other known adult males within the Ceroplastinae.

Materials and methods

Adult egg-laying *C. rusci* females, previously collected off *Ficus carica* in Kalamata (37º04'N-21º49'E), Greece, in April 2007, were placed on *F. carica* trees growing in the Experimental Farm of the Faculty of Agriculture, Legnaro, Padua district, (45º20'50''N-11º57'35''E), Italy, and their male and female offspring were reared during the summer of 2007 to obtain all the instars. Male specimens of each stage were slide mounted according to the procedures of Ben-Dov and Hodgson (1997). Measurements and numbers are given as ranges, followed by the mean in parentheses. Adult male terminology follows that of Giliomee (1967).

Ceroplastes rusci (Linnaeus)

Material examined: 15 adult males, 10 2nd-instar male nymphs, 10 prepupae, 14 pupae.

ADULT MALE (Fig. 1). Described from 8 males in fairly good condition; details checked on remaining specimens.

Mounted material: total body length 1296–1386 (1386) μm; maximum width across triangular plates 298–432 (390) μm. Antennae short, about 1/3rd total body length. Body and appendages covered with numerous setae, mostly fleshy setae (*fs*); hair-like setae (*hs*) fewer. Dermal pores entirely absent. Hamulohalteres absent. Abdominal glandular pouches and associated setae present. Caudal extensions present on abdominal segments VII and VIII. Penial sheath about ¼th total body length.

Head. Bluntly triangular in dorsal view; length from apex to pronotal ridge (*prnr*) 163–185 (175) μm, width across genae 196–237 (215) μm. Median crest (*mc*) showing polygonal reticulations; dorsal head setae: with 6–10 (8) *fs* and 6–14 (9) *hs* setae. Dorsal mid-cranial ridge absent; ventral midcranial ridge (*vmcr*) strong and well developed, extending anteriorly from anterior margin of ocular sclerite to short lateral arms of mid-cranial ridge. With 2 ventral midcranial ridge setae. Genae (*g*) unsclerotised, with polygonal reticulations and 22–30 (26) *fs* and 8–12 (9) hair-like genal setae (*gs*) on each side. Simple eyes: two pairs, subequal in size, rounded, in some specimens cornea of ventral simple eye stretched sagittally; dorsal eyes situated near head apex, each 36–42 (39) μm wide; ventral eyes on posterior ventral area of head, each 41 μm wide. Ocelli situated laterally, each 15–20 (17) μm wide, lying just anterior to postocular ridge; interocular ridge absent. Ocular sclerite fairly well sclerotised, with polygonal reticulations throughout. Preocular ridge distinct but short; postocular ridge strongly developed. Dorsal ocular setae (*dos*): 4–5 *fs* and 1 *hs* seta. Ventral head setae: 15 –24 (21) *fs*, mainly situated antero-laterally to ventral simple eyes. Preoral ridge fairly well developed and ∩- shaped, about 21 μm long, detected in only 2 specimens. Cranial apophysis (not illustrated) fairly well defined, with bifurcate apex, 15–33 (23) μm long.

Antennae: ten-segmented and filiform, with short, stout *fs* 25–29 (27) μm long; antennae 536–641 (560) μm long; shorter than half body length (ratio of total body length to antennal length 1: 0.41–0.46. average 0.44), shorter than posterior leg (ratio of posterior leg length to antennal length 1:0.17–0.21, average 0.20) and longer than penial sheath (ratio of penial sheath to antennal length 1:1.56–1.68, average 1.63). Scape subrectangular in shape, each 32–38 (36) μm long, 33–44 (39) μm wide; with 3 hair-like setae. Pedicel, each 33–42 (38) μm long, 28–36 (32) μm wide; with 5 or 6 *fs* and 4 or 5 *hs*, and distally with polygonal reticulations. Segment III long and generally club-shaped, but shape somewhat variable, each 3–5 (3.35) times longer than wide; each 70–75 (72) μm long, 15–25 (21) μm maximum width, with 9–13 (11) *fs* and 2 *hs*. Segments IV–IX cylindrical, each about 16–26 (20) wide; lengths (μm): IV: 99–110 (105); V: 83–93 (87); VI: 64–73 (67); VII: 65–73 (67); VIII: 46–53 (51); IX: 41–62 (48); setal distribution: IV 18–27 (22), V 18–20 (19), VI 15–26 (19), VII 12–28 (19), VIII 12–15 (14), IX 13–15 (14) *fs* respectively; *hs* absent. One antennal

bristle distinctly larger than fleshy setae present on segments VIII and IX, each 30–38 (33) μm and 32–41 (35) long. Segment X 55–70 (61) μm long, 16–29 (21) μm wide; with 8 or 9 *fs*, 1 or 2 *hs*, 3–5 (4) antennal bristles, each 41–58 (48) μm long, and 3 subapical capitate setae, each 41–58 (48) μm long; with apex constricted.

Thorax. Prothorax: membranous; pronotal ridges (*prnr*) well developed, interrupted by a weak sclerotisation dorsomedially; pronotal sclerite (*prn*) present, without lateral pronotal setae. Median pronotal setae absent; post-tergite apparently absent. Prosternum lightly sclerotised; bounded posteriorly by a strong transverse ridge, with median ridge well developed; with total of 6–12 (10) fleshy prosternal setae (stn_1s). Anteprosternal fleshy setae 4–6. Antemesospiracular setae: 3 pairs.

Mesothorax: mesoprephragma with pronounced ventral emargination. Prescutum (*prsc*) 85–122 (105) μm long; 170–196 (185) μm wide; heavily sclerotised, showing regular polygonal nodulations; anterior margin curved; laterally bounded by heavily sclerotised prescutal ridges (*pscr)* and posterior margin of prescutum bounded by prescutal suture (*pscs*). Scutum (*sct*): with median membranous area trapezoidal or sub-rectangular, slightly wider posteriorly; 67–93 (78) μm long; 174–207 (187) μm wide; scutal setae (*scts*): 10–12 (11) *fs* and 6–10 (8) *hs*. Rest of the scutum heavily sclerotised and showing polygonal nodulations, but without setae. Scutellum (*scl*) 44–55 (48) μm long, 185–207 (195) μm wide; tubular, with oval ventral foramen small; without either a scutellar ridge or scutellar setae. Prealare (*pra*) and triangular plate well developed. Mesopostnotum (pn_2) well developed; postnotal apophysis (*pna*) and postalare well developed and strongly sclerotised. Postalare (*pa*) without nodulation anteriorly and without postalare setae. Mesopostphragma with deep emargination. Mesopleural apophysis and mesopleural wing process well developed. Basalare well developed. Subalare present. Mesepisternum (eps_2) well sclerotised, with fairly defined nodulations; subepisternal ridge well developed. Mesepimeron not detected and probably undeveloped. Lateropleurite broad. Basisternum (stn_2) 122–148 (136) μm long, 246–270 (266) μm wide; with strong medial ridge and bounded anteriorly by strong marginal ridge (*mr*) and posteriorly by a strong precoxal ridge; without setae; furca (*f*) well developed, narrow waisted, with arms divergent and extending about ¾ way to marginal ridge anteriorly. Mesothoracic spiracle (sp_2) with well-developed peritreme; width of peritreme 16–22 (20) μm; post-mesospiracular setae (pms_2): 31–36 (34) *fs*, arranged in a band across segment between spiracles. Tegula (*teg*) present, with 4–6 (5) tegular hair setae (*tegs*).

Metathorax: metapostnotum not detected and probably absent; metatergal setae not detected on available specimens; dorsospiracular setae: 4–6 *fs*. Metapleural ridge reduced, with dorsal half absent, metapleural ridge wing process absent. Metasternum weakly sclerotised; anterior metasternal setae (*amss*) 15–20 (18) fleshy setae; posterior metasternal setae (*pmss*) 18–25 (20) fleshy setae. Metepisternum membranous, with 5–8 (6) fleshy postmetaspiracular setae (in Fig.1, covered by metathoracic coxa); precoxal ridge well developed, with metepimeron not detected and probably reduced or absent. Metathoracic spiracle (sp_3) similar to mesothoracic one; width of peritreme 17–25 (21) μm.

Wings (not illustrated): hyaline; rather short and comparatively broad; each 819–938 (884) μm long and 343–447 (405) μm wide; ratio of width to length 1:2.1–2.39 (2.18); ratio of total body length to wing length 1:0.63–0.68 (0.67); alar lobe and alar setae absent. Hamulohalterae absent.

Legs: long and slender, metathoracic leg longest, prothoracic leg subequal to mesothoracic; total lengths (μm): I: 592–629 (615); II: 592–659 (622); III: 636–928 (733) μm; ratio of hind leg to total body length 1:1.5–2.0 (1:1.8). Coxae (*cx*): I: 52–67 (61); II: 63–81 (69); III: 67–85 (76) μm long; setae of coxa III: 20–22 (21) *fs* and 4–6 (5) *hs*. Trochanter + femur lengths (μm): I: 185–233 (210); II: 185–204 (194); III: 166–211 (193); maximum widths: I: 30–46 (38); II: 31–49 (39); III: 34–51 (40); ratio of maximum width to length of hind femur 1:4.1–4.9 (4.8); with 2 oval sensilla on each side of trochanter. Trochanter III with 10–18 (13) *fs* and 2–4 *hs*; femur III with 23–31 (28) *fs* and 4–8 (6) *hs*. Tibia (*ti*): I: 252–274 (265) II: 229–281 (260); III: 263–296 (283) μm long; ratio of length to width of tibia III 1:14–16 (15); tibia III with 40–51 (47) *fs*; 8–12 (10) *hs*, more numerous near apex; with one tibial spur (*tibs*) on inner margin, 22–26 (24) μm long. Tarsi one-segmented: I: 93–96 (94); II: 97–102 (100); III: 99–103 (101) μm long; ratio of length of tibia III to length of tarsus III 1:0.37–0.35 (0.36); tarsus III (tar_3) with 20–22 (21) *fs*, 8–10 (9) *hs*; tarsal campaniform pores absent; tarsal digitules capitate, each 22–29 (26) μm long. Claws slightly curved and pointed, with a minute claw denticle: length III 19–23 (21) μm, claw digitules capitate, each 22–26 (24) μm long.

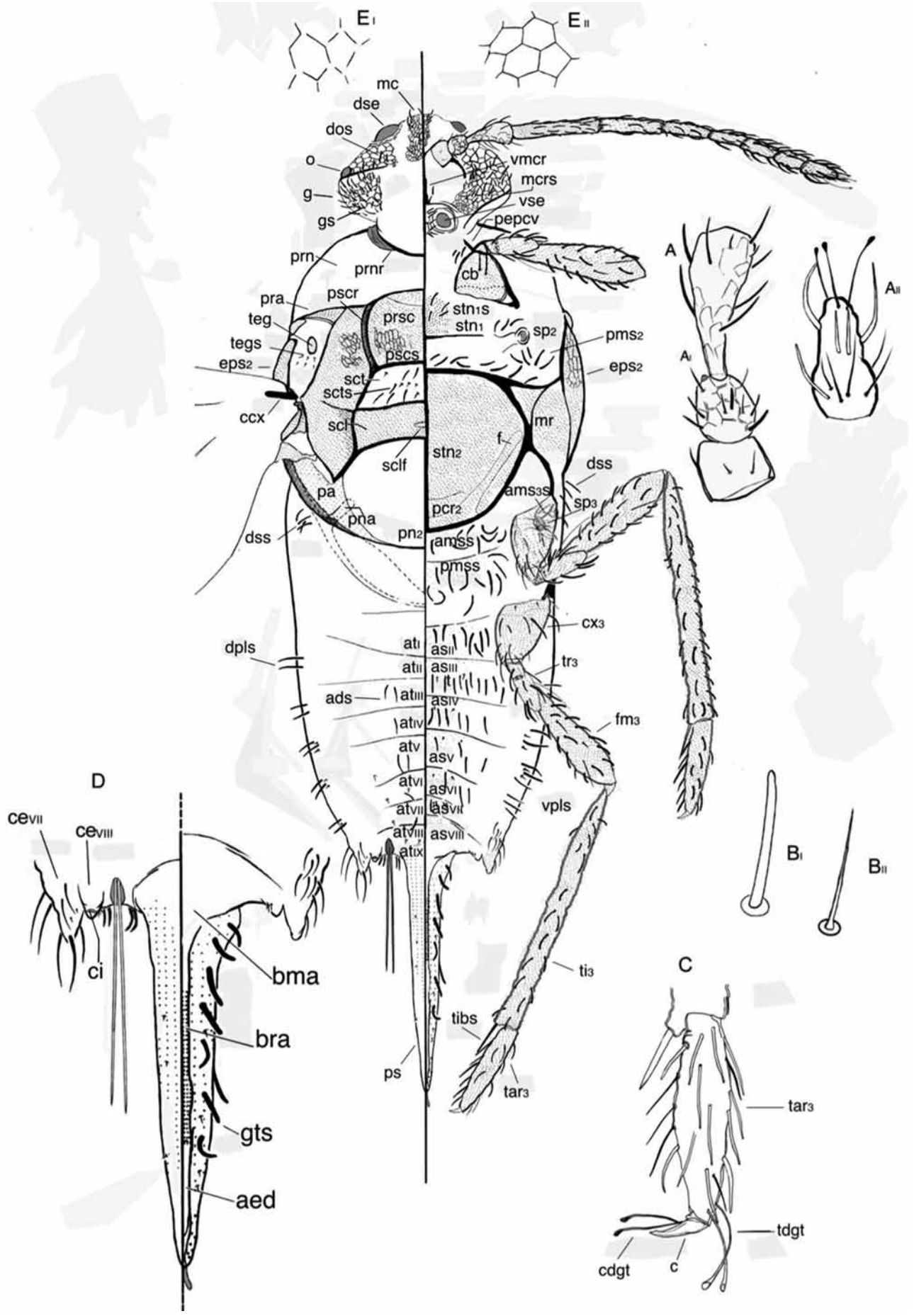
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FIGURE 1. *Ceroplastes rusci* (Linnaeus), adult male. Where: A = antennal segments: A_I = segments I–III, A_{II} = segment X; B = body setae: B_I = fleshy seta, B_{II} = hair seta; C = metatarsus and claw; D = dorsal and ventral view of the genital segment; E = dorsal (E_I) and ventral (E_{II}) view of polygonal reticulations on head capsule. And where ads = dorsal abdominal setae; aed = aedeagus; ams_3s = ante metaspiracular setae; amss = anterior metasternal setae; as_{II}– as_{VIII}= abdominal sternite II–VIII; at_I – at_{VIII} = abdominal tergite I–VIII; bma = basal membranous area; bra = basal rod of aedeagus; c = claw; cb = coxal bristles; ccx = costal complex of wing veins; cdgt = claw digitules; ce_{VII} = caudal extension of segment VII; ce_{VIII} = caudal extension of segment VIII; ci = dorsal cicatrix; ncx_3 = coxa of methathoracic leg; dos = dorsal ocular setae; dpls = dorsopleural setae; dse = dorsal simple eye; dss = dorsal spiracular setae; eps_2 = mesepisternum; f = furca; fm_3 = femur of metathoracic leg; g = genae; gs = genal setae; gts = genital fleshy setae; mc = median crest; mr = marginal ridge; o = ocellus; pa = postalare; pepcv = proepisternum + cervical sclerite; pms_2 = post mesospiracular setae; pmss = posterior metasternal setae; pn_2 = mesopostnotum; pna = postnatal apophysis; pra = prealare; prn = lateral pronotal sclerite; prnr = pronotal ridge; prsc = prescutum; ps = penial sheath; pscr = prescutal ridge; pscs = prescutal suture; scl = scutellum; sclf = scutellar foramen; sct =scutum; scts = scutal setae; sp_2 = mesothoracic spiracle; sp_3 = metathoracic spiracle; stn_1 = prosternum; stn_1s = prosternal setae; stn_2 = basisternum or mesosternum; tar_3 = tarsus of metathoracic leg; tdgt = tarsal digitules; teg = tegula; tegs = tegular setae; ti_3 = tibia of metathoracic leg; tibs = tibial spur; tr_3 = trochanter of metathoracic leg; vmcr = ventral midcranial ridge; vpls = ventropleural setae; vse = ventral simple eye.

Abdomen. Segments I–VII: tergites (*at*) I & II mainly unsclerotised, III–VII slightly sclerotised; sternites (*as*) II–VII fairly well sclerotised. Caudal extension of segment VII (ce_{VII}) very prominent and tapering, fairly well sclerotised ventrally, usually with pleural setae situated near apex longer and spine-like than basally. Dorsal abdominal setae (*ads*) (totals): I & II absent; III 4 *fs*; IV 4 *fs* + 4 *hs*; V 4–8 *fs* + 4 *hs*; VI 4 *fs* + 4–8 *hs*; VII 0–2 *fs* + 4 *hs*. Pleural setae: dorsopleural setae (*dpls*) (on each side): I absent; II & III 2 *fs*; IV 2–4 *fs* + 2 *hs*; V 1–4 (2) *fs* + 2 *hs*; VI 2–4 *fs* + 2 *hs*, and VII 4–6 *fs* + 2 or 3 *hs*. Ventropleural setae (on each side): I absent; II 4 *fs* + 1 *hs*; III 2 *fs*; IV 2 *fs* + 2 *hs*; V 2–4 *fs* + 2–4 *hs*; VI 2–4 *fs*; VII 7–10 (9) *fs* + 2 *hs* on VII. Ventral abdominal setae (totals): II 20–24 (23) *fs*; III 16–20 (18) *fs* + 2 *hs*; IV 8–12 *fs* + 2 *hs*; V 6–10 *fs* + 2 *hs*; VI 6–10 (8) *fs* + 2 *hs*; and VII 4–6 *fs* + 2 *hs* (sometimes 4–6).

Segment VIII: tergite and sternite sclerotised; dorsal abdominal setae (*ads*) (total): 4 hair setae; dorsopleural setae (*dpls*) (on each side): 2 *fs* + 2 *hs*; ventropleural setae (on each side): 2–4 *fs* + 2 *hs*; sternite without ventral abdominal setae; caudal extension of segment VIII (ce_{VIII}) weakly sclerotised, forming a prominent semi-circular lobe; dorsal cicatrix present (*ci*); nodulations not detected on ce_{VIII}; glandular pouches present, each with 2 long flagellate setae, each 138–177 (163) μm long; protruding part about 5 times as long as section within pouch. Small tergal plate of segment IX present; ante anal setae: 4 or 5 (*fs*) and 3 hair setae on each side of posterior margin of segment VIII.

Genital segment: penial sheath (*ps*) long, with parallel sides but these diverging anteriorly, posteriorly with a pointed apex, this produced into a small and finger-like membranous extension; anal opening less than 1.5 μm wide; penial sheath with a group of small sensilla near apex; also with genital setae (*gts*): 16–28 (23) *fs* and 12-20 (15) minute hair penial sheath setae, mainly ventrally on margins; fleshy setae absent on apical portion of penial sheath. Penial sheath 344–381 (361) μm long and 80–84 (82) μm wide at base; ratio of total body length to penial sheath length about 1:3.7. Basal rod (*bra*) distinct, 145–188 (166) μm long and about 19 μm wide, positioned just posterior to basal membranous area (*bma*) of aedeagus. Aedeagus (*aed*) with parallel sides, 203–222 (213) μm long.

SECOND-INSTAR MALE NYMPH (Fig. 2)

Described from 10 specimens in good condition.

Unmounted material: body oval, lightly convex dorsally, brown in colour.

Mounted material: body elongate oval; 1043–1267 (1150) μm long; 581–745 (654) μm wide; anal cleft short.

Dorsum: derm membranous. Preopercular pores absent and other dorsal pores not seen. Tubular ducts (I) in a single row along body margin, except posterior 1/3 of margin, where absent; each duct with a cup-shaped invagination: 4–6 (5) μm wide; outer ductule: 19–24 (23) μm long; inner ductule: 20–23 (21 μm) long, terminal gland: 3–6 (5) μm wide; distribution of ducts: 11–13 between eyespots, 5 or 6 between eyespot and anterior spiracular furrow, 6 between anterior and posterior spiracular furrows, 6 posterior to each posterior spiracular area. Anal plates each subtriangular, broad, with inner margins slightly diverging; each plate 29–45 (37) μm broad; anterior margin 39–49 (39) μm long; posterior margin 45–54 (49) μm, inner margin 55–58 (56) μm long; each plate with 1 posterior margin seta, 26–30 (26) μm long, 2 inner margin setae, 16–20 (18) μm and 19–25 (21) μm long respectively, plus one apical seta, 16–19 (18) μm long. All anal plate setae slightly spinose. Anogenital fold with 3 pairs of anterior margin setae and 2 pair of lateral margin setae. Anal ring with 6 setae.

Margin: marginal setae (J) setose, 7–10 (8) μm long, sometimes curved, arranged in a single marginal line; with 8 or 9 between eyespots, and, on each side, 2 between eyespot and anterior spiracular area, 2 between anterior and posterior spiracular area, and 8–10 (9) between posterior spiracular area and anal cleft; with one longer setose seta on each anal lobe, 29–36 (32) μm long. Stigmatic clefts shallow, each with 3 short, conical stigmatic spines (H), median spine longest and slightly set onto dorsum, 13 μm long and 6 μm wide at base; lateral setae each 9–12 (10) μm long and 4 μm wide at base.

Venter: derm membranous, segmentation obscure; minute dermal spinules (Fi) most frequent around anal cleft. Ventral microducts (C), each about 1.5 μm wide, sparsely distributed in a submarginal band. Ventral setae (E) bristle-like, each 1–2 μm long, present submarginally and submedially on each abdominal segment. Two pairs of interantennal setae present: shorter pair 4–9 (7 μm) long, longer pair 23–37 (34 μm) long respectively. Antennae (A) 6-segmented, each 131–151 (141) μm long, third segment longest; dimensions (μm): segment I: 22–25 (23) long; II: 16–19 (17) long; III: 39–46 (43) long; IV: 12–15 (13) long; V: 13–16 (15) long; VI: 23–30 (27) long; antennal setae: segment I: 3 *hs*, longest 15–30 (24) μm long; II: 2 *hs*, longest 32–38 (36) μm, campaniform pore present, 2–3 μm wide; III: 3 *hs*, longest 29–38 (33) μm long; IV: 1 *fs*, 9–15 (13) μm long; V: 1 *hs*, 22–28 (24) μm long, plus 1 *fs* 13 μm long; VI: 4 *hs* and 4–6 *fs*, longest apical seta 44–55 (48) μm long. Spiracles: peritremes 12–13 μm wide; each usually with 6 spiracular disc-pores (B) but mesothoracic spiracle sometimes with 5 or 7 disc-pores, mainly quinquelocular, rarely with 3 or 4 loculi, each pore about 3 μm wide, forming a band from each spiracle to body margin. Legs (D) well developed, without tibio-tarsal scleroses. Coxae: 51–58 (54) μm long and 29–38 (33) μm wide; with 4 setose setae, longest 15–28 (20) μm long. Trochanter + femur: 74–83 (78) μm long, 22–25 (24) μm wide; trochanter with 2 setose setae, longest 19–35 (28) μm long; femur with 1 short setose seta. Tibia 51–57 (54) μm long and 15–16 (16) μm wide; with 2 setose setae, longest 13–17 (16) μm long. Tarsus 41–44 (42) μm long and 13–15 (13) μm wide; with 4 setose setae, longest 10–13 (11) μm long; tarsal digitules each 30–36 (33) μm long. Claws each with a denticle; claw digitules unequal, one broad apically, the other slender and knobbed at apex, each 16–19 (17) μm long.

Comments: the only described *Ceroplastes* 2nd-instar male nymphs are those of *C. sinensis* and *C. japonicus* (Qin & Gullan, 1994; Rainato & Pellizzari, 2008). Comparison with these descriptions suggests that the 2nd-instar male nymphs of these three species are very similar, the main differences appearing to be in the number of spiracular disc-pores, marginal setae and dorsal tubular ducts: *C. rusci* and *C. sinensis* have 6 spiracular disc-pores whereas *C. japonicus* has 8–12 (10); *C. rusci* has 8 or 9 marginal setae anteriorly between eyespots whereas *C. japonicus* has 5 or 6; *C. rusci* has 11–13 (12) dorsal tubular ducts between the eyespots whereas *C. japonicus* has 6–11 (9). In addition *C. rusci* has a denticle on the claw, which is absent on the claws of *C. japonicus* and *C. sinensis*.

PREPUPA (Fig. 3)

Described from 7 specimens in fairly good condition. Details checked on remaining 3 specimens.

Unmounted material: reddish brown in colour.

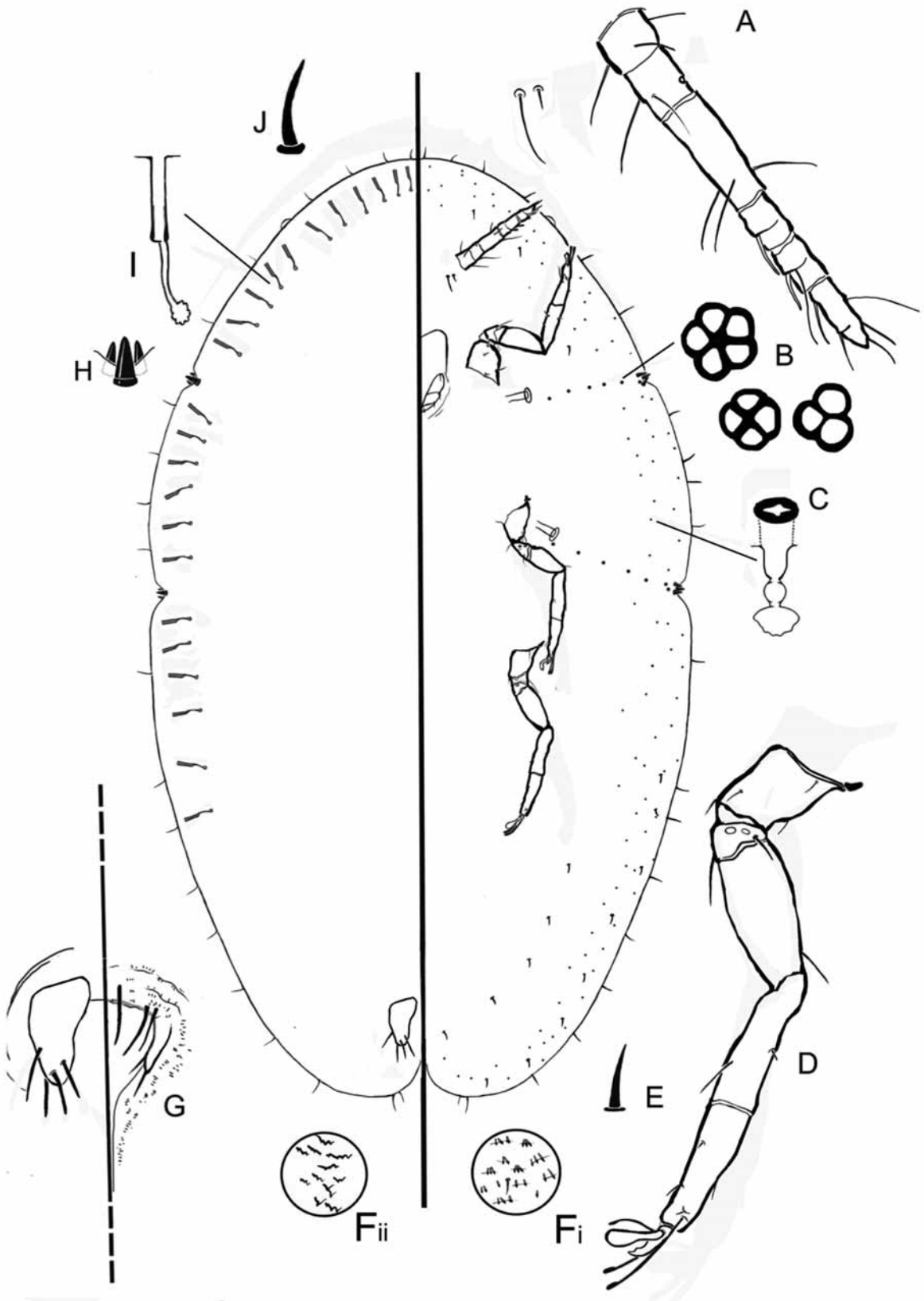

FIGURE 2. *Ceroplastes rusci* (Linnaeus), 2nd- instar male nymph. Where: A = antenna; B = spiracular disc-pores; C = ventral microduct with cruciform pore; D = metathoracic leg; E = abdominal ventral seta; Fi = ventral dermal spinules; Fii= dorsal dermal spinules; G = dorsal view of anal plates (left) and view of the ano-genital fold (right) ; H = stigmatic cleft; I = dorsal tubular duct; J = marginal seta.\

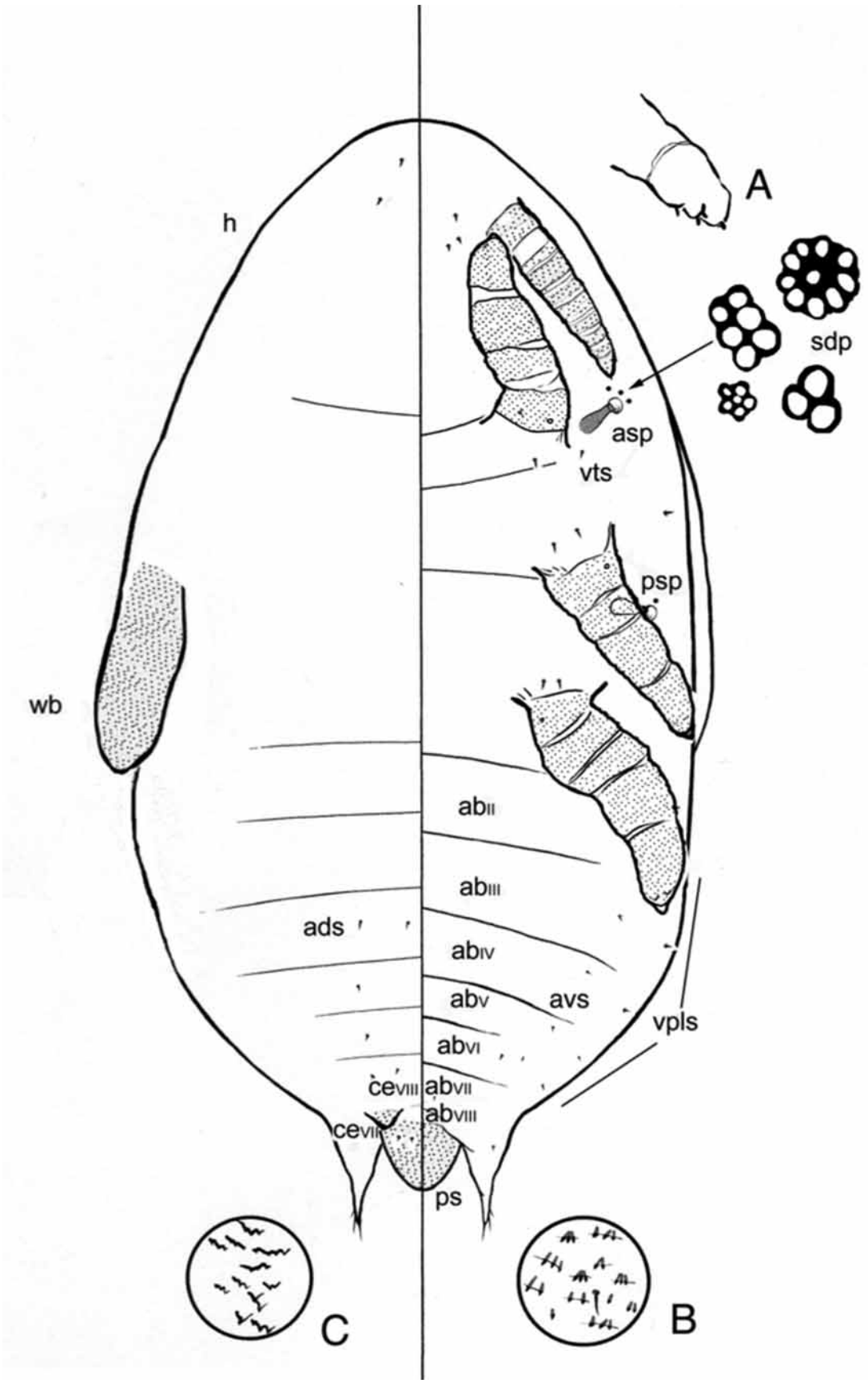

FIGURE 3. ***C****eroplastes rusci* (Linnaeus), prepupa. Where: A = antenna; B = ventral dermal spinules; C = dorsal dermal spinules. And where ab II–VIII = abdominal segments II–VIII; ads = dorsal abdominal setae; asp = anterior spiracle; avs = ventral abdominal setae; ce_{VII} = caudal extension of segment VII; ce_{VIII} = caudal extension of segment VIII; h = head; ps = penial sheath; psp = posterior spiracle; sdp = spiracular disc-pore; vpls = ventropleural setae; vts = ventral thoracic setae; wb = wing bud

Mounted material: body elongate, narrowest anteriorly, widest across abdomen, length 1073–1118 (1098) μm, width across abdomen 521–611 (556) μm. Division into head, thorax and abdomen not clear. Segmentation fairly defined, most distinct on abdomen.

Head: lacking mouthparts and simple eyes. Antennae (A) fairly-well sclerotised, elongate, each 202–229 (218) μm long, with 9 poorly defined segments; antennal length to body length ratio 1:4.87–5.17 (5.05); antennal setae: IX: with 4 or 5 minute *fs*. With 2, sometimes 3, pairs of minute interantennal setae ventrally, each 3–4 μm long, plus 2 minute setose dorsal head setae, each 4–9 (7) μm long.

Thorax: prothoracic legs directed anteriorly, other pairs directed posteriorly; claws and digitules extremely reduced; metathoracic legs each 167–215 (191 μm) long. Wing buds (*wb*) each 185–277 (236) μm long, 85–96 (91) μm wide, ratio of length to width 1: 0.34–0.46 (0.38). Spiracles (*asp* & *psp*): width of peritremes 17–20 (19) μm, each with a group of 3 spiracular disc-pores (*sdp*) near atrium; each pore mainly with six loculi and about 4 μm wide, but number of loculi highly variable. Setae: on each side, 1 or 2 minute ventral thoracic setae (*vts*) near each coxa, and 1 minute fleshy ventropleural seta on each side of mesothorax.

Abdomen: segmentation fairly well defined; minute dermal spinules most frequent posteriorly; dermal spinules with a different pattern on dorsum with respect to venter. Setae: pairs of minute dorsal abdominal setae (*ads*) present medially on segments IV–VII, each about 4–6 μm long; with a pair of ventral abdominal setae (*avs*), each 4–6 μm long, submedially on segments III–VII; with one ventropleural seta (*vpls*) on each side of segments III–VI, each seta 9–10 μm long; Margins with minute ventropleural setae, each 6–13 (9 μm) long, with a single seta on each side of each segment. Caudal extension VII (ce_{VII}) fairly well sclerotised, 46–58 (52) μm long and 22–25 (24 μm) wide, with 2 longer hair-like setae apically, each 26–32 (30) μm long, plus a shorter seta, 10–13 (11) μm long on outer margin; with also 1 ventropleural seta at base of ce_{VII}. Caudal extension VIII (ce_{VIII}) poorly developed, but fairly well sclerotised. Penial sheath sclerotised, roundly triangular in shape, 36–38 μm long and 34–36 μm wide, ratio of length to width close to 1, with 2 minute penial sheath setae dorsally.

Comments: the only *Ceroplastes* prepupa which has been described previously is that of *C. japonicus* (Rainato & Pellizzari, 2008). They appear to be very similar although the head setae and interantennal setae are possibly more numerous on *C. rusci*. In addition, *C. rusci* has only 3 spiracular disc pores associated with each spiracle whereas *C. japonicus* has 6–12 (8).

PUPA (Fig. 4)

Described from 14 specimens in good condition.

Unmounted material: reddish brown in colour.

Mounted material: elongate oval, narrower anteriorly, widest across abdomen, length 967–1222 (1126) μm, maximum width across abdomen 447–492 (473) μm. Derm membranous. Divisions into head, thorax and abdomen and segmentation poorly defined, latter most distinct on abdomen.

Head: lacking mouthparts and simple eyes. Antennae somewhat sclerotised, elongate, directed posteriorly, each antenna 370–529 (477 μm) long with 10 poorly defined segments; antennal length to body length ratio 1:2.31–2.62 (2.34); with several minute fleshy setae towards the apex of terminal segments; antennal setae distribution: X: 7; IX: 1, VIII: 1; each about 3 μm long. With 2 pairs of dorsal head setae anteriorly on head, each about 9–10 μm long; ventrally with 3 pairs of head setae, each 6–7 μm long: 2 head setae present anterior to scape and 1 posterior to it.

Thorax: legs well developed, each with clear segmentation; prothoracic legs C–shaped, extending anteriorly, almost meeting in front of head, other pairs directed posteriorly; procoxae with one minute seta; metathoracic legs each 463–555 (490) μm long. Wing buds (*wb*) each 444–555 (491) μm long and 130–185 (156) μm wide; ratio of length to width 1:0.29–0.33 (0.31). Spiracles (*asp* & *psp*): width of peritremes 19–23 (22) μm, each anterior spiracle with 8–11 (8) spiracular disc-pores (*sdp*) near atrium, each about 4 μm wide, and each posterior spiracle with 3–5 (4) disc-pores; number of loculi highly variable, ranging from 3 to 11 loculi. Setae: ventrally with 1 very small thoracic seta (*vts*) near each coxa, plus 1 laterally on mesothorax.

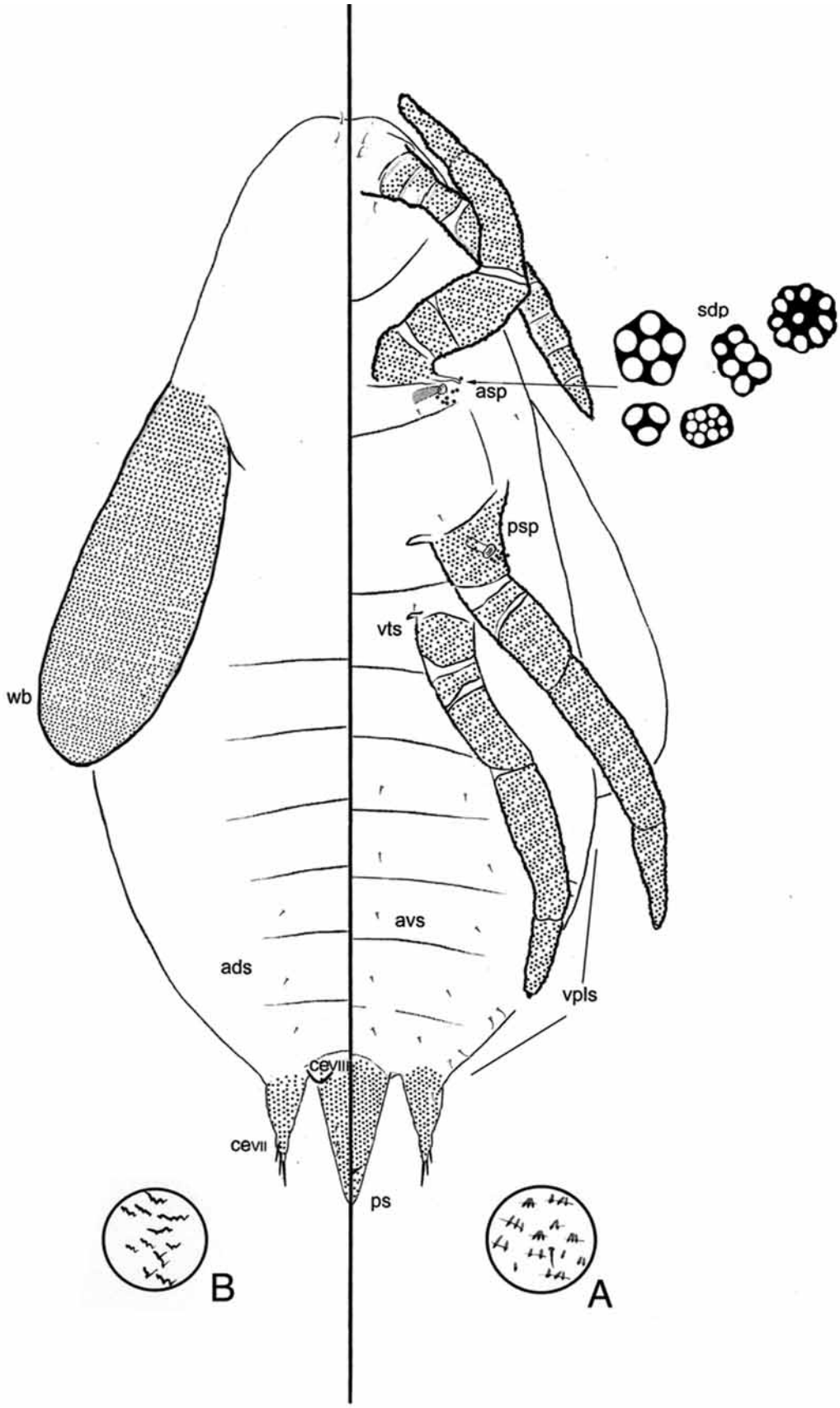

FIGURE 4. *Ceroplastes rusci* (Linnaeus), pupa. Where A = ventral dermal spinules; B = dorsal dermal spinules. And where ads = dorsal abdominal setae; asp = anterior spiracle; avs = ventral abdominal setae; ce_{VII} = caudal extension of segment VII; ce_{VIII} = caudal extension of segment VIII; ps = penial sheath; psp = posterior spiracle (covered by metathoracic leg); sdp = spiracular disc-pores; vpls = ventropleural setae; vts = ventral thoracic setae; wb = wing bud.

Abdomen: with rows of minute dermal spinules; dermal spinules with a different pattern on dorsum (C) with respect to venter (B; segmentation fairly defined. Setae: with a pair of dorsal abdominal setae (*ads*), each about 4 μm long, on segments V–VII; with 2 pairs of ventral abdominal setae (*avs*) on segments III–VII, each about 4 μm long + 2 ventropleural setae (*vpls*) on each side of segments IV–VI, each seta 9–10 μm long; anteanal setae not detected. Caudal extensions on segment VII (ce_{VII}) well developed and fairly sclerotised, each 83–97 (93) μm) long and 29–58 (44) μm wide at base; each with 2 spinose setae apically, 25–38 (32) μm and 22–33 (28) μm long respectively, + 1 hair-like seta, 12–22 (16) μm long, on lateral margin. Caudal extensions on segment VIII (ce_{VIII}) poorly developed and fairly well sclerotised, each 18–29 (23) μm long and 18–32 (24) μm wide at base; setae absent on ce_{VIII}. Penial sheath (*ps*) elongate-triangular, sclerotised, 120–167 (148) μm long, 73–96 (89) μm wide at base, ratio of length to breadth 1:0.60; with 3 pairs of minute hair setae dorsally. Anal opening at base of penial sheath about 10 μm wide.

Comments: the only pupa of a *Ceroplastes* species described previously is that of *C. japonicus* (Rainato & Pellizzari, 2008). The main difference is in the number of spiracular disc-pores, with *C. rusci* having 8–11 (9) near each anterior spiracle and 3–5 (4) near each posterior spiracle, whereas *C. japonicus* has 10–16 (13) near each anterior spiracle and 7–10 (9) near each posterior spiracle.

Key to *Ceroplastes* species based on adult males

The key to adult male *Ceroplastes* and *Waxiella* (Rainato & Pellizzari, 2008) is modified to include *C. rusci*.

1 Penial sheath with fleshy setae ..... *Ceroplastes* spp...2
- Penial sheath without fleshy setae ..... *Waxiella* spp…5
2 Penial sheath apex rounded; fleshy setae absent on basal portion of penial sheath; glandular pouches absent .... *C. ceriferus*
- Penial sheath apex pointed; fleshy setae present on basal portion of penial sheath; glandular pouches either present or absent 3
3 Glandular pouches absent ..... *C. japonicus*
- Glandular pouches present 4
4 Penial sheath about 360 μm long; ratio of total body length to penial sheath length 1:3.7 ..... *C. rusci*
- Penial sheath about 185 μm long. Ratio of total body length to penial sheath length 1:6.2 ..... *C. cirripediformis*
5 Scutal fleshy setae numbering 10–20 ..... *W. berliniae*
- Scutal fleshy setae numbering 2–11 ..... *Waxiella* sp.

Comments

The main differences among the adult males of *C. ceriferus*, *C. cirripediformis*, *C. japonicus*, *C. rusci*, *W. berliniae* and *Waxiella* sp. (Giliomee, 1967; Gimpel *et al*., 1974; Rainato & Pellizzari, 2008) are:

1) Distribution of fleshy setae on penial sheath: *C. rusci* shares the presence of fleshy setae on the basal portion of the penial sheath with *C. japonicus* and *C. cirripediformis*, which are absent on *C. ceriferus*. Known *Waxiella* males do not have any fleshy seta on penial sheath.

2) Presence of glandular pouches: glandular pouches are present on *C. cirripediformis*, *C. rusci*, *W. berliniae* and *Waxiella* sp. but are absent on *C. japonicus* and *C. ceriferus.*

3) Shape of penial sheath apex: the apex is pointed in *C. cirripediformis*, *C. japonicus*, *C. rusci*, *W. berliniae* and *Waxiella* sp. but is broadly rounded in *C. ceriferus*.

4) Number of scutal setae: *C. ceriferus* has about 45, whereas *C. cirripediformis*, *C. japonicus* and *C. rusci* each have about 19–23 scutal setae. *Waxiella berliniae* has an average 24 and *Waxiella* sp. 18.

5) Length of penial sheath: within *Ceroplastes*, this is clearly longest on *C. rusci* (mean about 360 μm), of medium length in *C. japonicus* (mean about 265 μm) and *C. ceriferus* (mean about 235–260 μm) and shortest in *C. cirripediformis* (mean about 185 μm). *Waxiella* males have a long penial sheath: mean 400 μm in *W. berliniae* and 426 μm in *Waxiella* sp..

Discussion

The morphology of the adult females of *Ceroplastes* species has been used to predict their geographical origin based on cladistic analysis (Qin *et al*., 1994). At present, the adult male morphology of only 6 Ceroplastinae is known from a total of 155 species recorded worldwide (Ben-Dov *et al*., 2009). This is far too few to allow an analysis of relationships among species and cannot help in clarifying the native areas of some species (i.e. *C. japonicus*). However, we offer a few suggestions below.

Among the *Ceroplastes* males, *C. rusci* and *C. cirripediformis* share several diagnostic characters (see Table 1) even if *C. rusci* is believed to be native to the Afrotropical region (Qin *et al*., 1998) or to the Mediterranean basin (Balachowsky, 1933), whereas *C. cirripediformis* is a Neotropical species (Qin *et al*., 1998).

Ceroplastes ceriferus, a Neotropical species, is clearly morphologically distinct from the Neotropical *C. cirripediformis* and also from the other *Ceroplastes* adult males, due to its peculiar penial sheath features and number of scutal setae.

Ceroplastes japonicus was considered to be an Oriental species by Borchsenius (1957) whereas Qin *et al*. (1998) considered that it probably had a Neotropical origin. However, it differs from both the Neotropical *C. ceriferus* and *C. cirripediformis*, as indicated above.

Ceroplastes rusci shares several features with the Afrotropical *Waxiella* males (see Table 1), although it has fleshy setae on the basal portion of the penial sheath, which are absent from the two known *Waxiella* males. They appear to form a group, with an Afrotropical range, morphologically well separated from the other Ceroplastinae males.

TABLE 1. A comparison among morphological characters of *Ceroplastes* and *Waxiella* males and their supposed geographical origin. Morphological data for *C. cirripediformis* and *C. ceriferus* taken from Gimpel *et al*. (1974); data for *W. berliniae* and *Waxiella* spp. from Giliomee (1967); data for *C. japonicus* from Rainato & Pellizzari, 2008.

Species	Presence and distribution of penial sheath fleshy setae	Glandular pouches and associated setae	Shape of penial sheath apex	Number of scutal fleshy setae (*fs*)	Number of scutal hair setae (*hs*)	Ratio of total Body length to penial sheath length	Supposed origin
C. ceriferus	Absent on the basal portion of penial sheath	Absent	Rounded	*fs* + *hs*: about 45		1: 4.9–5.2	Neotropical
C. cirripediformis	present on the basal portion of penial sheath	Present	Pointed	*fs* + *hs* :about 23		1: 6.2	Neotropical
C. japonicus	present on the basal portion of penial sheath	Absent	Pointed	10–14 (12)	6–10 (8)	1: 4.0	Oriental or Neotropical
C. rusci	present on the basal portion of penial sheath	Present	Pointed	10–12 (11)	6–10 (8)	1: 3.7	Afrotropical or Mediterranean
W. berliniae	Absent	Present	Pointed	10–20 (14)	4–14 (10)	1: 3.6 – 4.1 (3.8)	Afrotropical
Waxiella sp.	Absent	Present	Pointed	2–11 (6.7)	9–12 (11)	1: 3.5 – 3.8 (3.6)	Afrotropical

Acknowledgements

We are very grateful to C. J. Hodgson for kindly reading the manuscript and for his valuable suggestions.

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