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RESEARCH ARTICLE

Millennial zoological mystery of medieval Persian scientists

Тысячелетняя зоологическая загадка средневековых персидских ученых

I.A. Gavrilov-Zimin & A.S. Kurochkin

И.А. Гаврилов-Зимин, А.С. Курочкин

Iya A. Gavrilov-Zimin, Zoological Institute, Russian Academy of Sciences, 1 Universitetskaya Emb., St Petersburg 199034, Russia. E-mail: coccids@gmail.com; coccids@zin.ru

Andrey S. Kurochkin, Department of Zoology, Genetics and General Ecology, Samara National Research University, 1 Akademika Pavlova str., Samara 443011, Russia. E-mail: nitidula@mail.ru

Abstract. Great medieval scientist-polymath Abu Rayhan Al-Beruni (973–1050) wrote in his book "Pharmacognosy" about some kind of "worms" inhabiting willows in Azerbaijan and Southern Iran and used by native people for producing of a red dye. It was unclear during one thousand years which organisms Al-Beruni noted as those dye-producing "worms". Some modern authors even suggested that the relevant medieval text was partly erroneous. To the contrary, in the present paper we, for the first time, consider some species of the felt scale insects (Coccinea: Eriococcidae) as the organisms, which have probably been used for the production of the red dye in the medieval countries of Western and Central Asia. These insects are several species from two closely related genera *Acanthococcus* Signoret, 1875 and *Gossyparia* Signoret, 1875. The review of biological characters, identification key, new figures and colour photographs are provided for the species of *Acanthococcus* and *Gossyparia* associated with *Salix* spp. in the Asiatic Region. *Acanthococcus turanicus* Matesova, 1967, **syn. nov.** is placed in synonymy with *A. salicis* (Borchsenius, 1938), and *A. altaicus* Matesova, 1967, **syn. nov.** is placed in synonymy with *A. spiraeae* Borchsenius, 1949. Earlier discovered synonymy of *A. melnikensis* (Hodgson et Trencheva, 2008) with *A. aceris* Signoret, 1875 is discussed. Some other dye-producing scale insects and their pigments are also briefly considered.

Резюме. Выдающийся средневековый учёный-энциклопедист Абу Райхан Аль-Беруни (973-1050) в своей книге «Фармакогнозия» упоминал неких красильных «червей», живущих на ивах в Азербайджане и Южном Иране и используемых местным населением для получения красной краски. На протяжении тысячи лет подлинная биологическая природа этих красильных организмов оставалась неясной, а некоторые современные авторы предполагали даже, что средневековый текст был частично ошибочным. В настоящей статье мы впервые показываем, что некоторые виды войлочников (Coccinea: Eriococcidae) вполне могли быть использованы для получения красной краски в средневековых государствах Западной и Центральной Азии. Эти виды относятся к двум близкородственным родам *Acanthococcus* Signoret, 1875 и *Gossyparia* Signoret, 1875. В статье содержится подробный биологический обзор таких видов, оригинальные рисунки и фотографии, а также определительный ключ для видов, отмечавшихся на *Salix* spp. в азиатском регионе. *Acanthococcus turanicus* Matesova, 1967, **syn. nov.** рассматривается в качестве младшего синонима *A. salicis* (Borchsenius, 1938); *A. altaicus* Matesova, 1967, **syn. nov.** помещается в синонимы *A. spiraeae* Borchsenius, 1949. Дополнительно обсуждается ранее установленная синонимия *A. melnikensis* (Hodgson et Trencheva, 2008) с *A. aceris* Signoret, 1875. Кратко рассматриваются также некоторые другие красильные виды кокцид и их пигменты.

Key words: scale insects, dye-producing insects, natural red dye, Al-Beruni, willow, *Acanthococcus*, *Gossyparia*, *Salix*

Ключевые слова: кокциды, красильные насекомые, красная краска, Аль-Беруни, войлочники, ива, *Acanthococcus*, *Gossyparia*, *Salix*

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Introduction

Ancient and medieval scientists of Europe and Central Asia often discussed different dye-producing plants and animals in their manuscripts. In spite of the fact that the modern historical and archaeological studies on this subject are very abundant and published in numerous papers and books (see for the general review: Cardon, 2007, 2014), some ancient texts still provide unexpected and important information. Thus, the great medieval scientist-polymath Abu Rayhan Al-Beruni (973–1050) (Fig. 1) wrote in his book "Pharmacognosy" about "worms" inhabiting some sort of willows (named "kirmaj") in Azerbaijan and Darabdjird (Fars Province of modern Iran) and used for producing of a red dye ("arjuwani"); these "worms" were scraped off the plant for further using (see modern edition: Beruni, 1973: 455, 711). Al-Beruni's note was based on data of Persian historian and philologist Hamza Al-Isfahani (about 893–961), but unfortunately without clear reference to the exact tractate of Al-Isfahani (Fig. 2). A lot of texts of Al-Isfahani were lost during centuries and/or were never translated in modern languages and it is rather problematic now to understand which Al-Isfahani's text could include the description of the dye-producing organisms. We suppose such information could be present in "Al-Hayes and Al-Muawa'n'ah Biaal'Arbyyat and Al-Farsiyat", because this manuscript included the data on the names of different plants and animals; now, the fragments of the Al-Isfahani's manuscript are preserved in some libraries in Cairo, Egypt (Brockelmann, 1937: 222) and we hope that in future philologists will try to combine these fragments and provide a modern translation and edition of them. For the present discussion, we shall use only the well-studied and well-translated "Pharmacognosy" of Al-Beruni. At least two modern translations of this book into European languages exist; both were published independently in 1973. The first one into Russian was done by U.I. Karimov under a general editing of the famous orientalist A.K. Arends and is comprising 1120 pages, including numerous comments. The second translation into English was done by H.M. Said & R.E. Elahie, with comments by S.K. Hamarneh, and is comprising about 960 pages (806 pp. + 152 pp. in two volumes), but with the inclusion of the Arabic text of Al-Beruni, which occupies about one half of the first volume. Thus, it seems that the Russian translation is significantly more comprehensive than the English one. We were able to find and study this Russian translation only, but it seems that the information on the dyeing organisms in both Russian and English translations is identical as we can judge comparing Russian text

Fig. 1. Abu Rayhan Al-Beruni (973–1050), portrait reproduced from Beruni (1973); painter I. Ikramov.

Книга фармакогнозии в медицине **711**

836. ḲИРМИЗ[1] قرمز — КЕРМЕСНЫЙ ЧЕРВЬ

Ал-Ḥāвӣ: ḳирмиз — это краска. Затем он говорит, что в силе *ḥабб ал-ḳирмиза*[2] содержится вяжущее свойство и немного горечи. Далее он говорит о *дӯд ал-ḳирмизе*[3], добываемом из дерева[4] в свежем и влажном виде.

Гален: когда его извлекают из дерева[5] и он свеж и влажен, то обладает охлаждающим и сушащим свойством. На полях [книги Галена сказано], что это *ṣӯфāнӣйа*[6], которой женщины румянят свои лица; [*ḳирмиз*] — *ḳуḳḳӯс бафӣḳӯс*[7].

*Ḥамза: *кирмадж*[8] — вид ивы, растущей в Азербайджане и Дāрāбджирде; он «плодоносит» красными червями, которых соскребывают и приготавливают из них *арджувāнӣ*[9].

[1] См. № 443 пр. 1.

[2] حب القرمز — «зерно *ḳирмиза*», так называются кермесные черви.

[3] دود القرمز — другое название кермесных червей; см. № 443.

[4] *A, B, C:* من اللحم — «из мяса»; *П:* از دريا — «из моря», т. е. он читает من البحر, мы читаем من الشجر ср. пр. 5.

[5] *A, B, C:* .... اذا أخذ من البحر و هو رطب, эту цитату из Галена приводят также Ghaf. 259 и ИБ. *Джāми*ʻ I 119: اذا اخذ هذا من الشجر و هو رطب طرى ... — «когда его извлекают из дерева и он еще свежий и влажный...».

[6] الصوفانية (?); ср. BB. 1683_{14} и Löw, Pf. 250: صرنوفا، صربوقا، صرفوقا

[7] *A, B, C:* تقوس يفيفوس, чит. ققوس بفيقوس — гр. κὸκκος βαφικος, Диоск. IV 41.

[8] كرمج

[9] الارجوانى — красная краска; ср. № 45 пр. 8. Отрывок *9 включен в Picture 130.

Fig. 2. Part of the page 711 from Beruni (1973); the information on “worms” from willow is underlined by us.

with the corresponding data provided by Donkin (1977: 852) who studied the English translation only.

During one thousand years period, the organisms reported by Al-Beruni as the dye-producing “worms”, which were scraped off the willows, has remained a mystery, especially, taking into an account the fact that the number of dye producing animals, known from the modern historical and archaeological literature is very limited and none of those animals inhabit willows. Excluding different dye-producing maritime mollusks (Muricidae and some Cephalopoda), all other dyeing animals belong to the insect order Homoptera, suborder Coccinea (“scale insects” in English or “cochenilles” in French) (see the most comprehensive review of the dye-producing organisms in Cardon, 2007). Scale insects were used for centuries to produce red-dye based on carmine and some related chemical substances (Fig. 3), which are relevant to a large class of natural chemicals, anthraquinones (see discussion at the end of this paper). Previously, only four taxonomic groups of scale insects have been clearly reported as

Fig. 3. Dried females of *Porphyrophora hamelii*, natural carmine and its chemical formula.

dye-producing: 1) different species of the genus *Porphyrophora* Brandt, 1833, especially *Porphyrophora polonica* (Linnaeus, 1758) and *P. hamelii* Brandt, 1833, inhabiting underground parts of different perennial herbs and grasses in Eastern Europe and Transcaucasia; 2) some species of the genus *Kermes* Boitard, 1828, especially *Kermes vermilio* (Planchon, 1864), inhabiting oak trees, *Quercus coccifera* (Fagaceae) and some others in the Mediterranean Region; 3) species of the genus *Dactylopius* Costa, 1829, especially *Dactylopius coccus* Costa, 1829, inhabiting *Opuntia* spp. (Cactaceae) in Central America and introduced to some other tropical and subtropical countries for dye-production after XV century; 4) species of the family Kerriidae, especially *Kerria lacca* (Kerr, 1782), inhabiting different tropical trees in the Oriental Region. In view of this limited number of the known dye-producing animals, some modern authors (see, for example, Donkin, 1977: 852; Jashenko & Ambartsumyan, 1999: 49, 52) suggested that the medieval text of Al-Beruni was partly erroneous and that Al-Beruni and Al-Isfahani kept in mind *Porphyrophora hamelii* or other *Porphyrophora* spp., but confused about what their host plant is. Meanwhile, *P. hamelii* inhabits exclusively underground parts of grasses (Poaceae) and it is impossible to have them "scraped off" from the plants; for dye-production, the insects are simply collected by hands when the adult females appear on the surface of ground for copulaion (Sarkisov, 1984). All other species of the genus *Porphyrophora* also inhabit roots of different herbs and grasses, except *Porphyrophora epigaea* Danzig, 1983, which may live not only on roots of herbaceous host plants, but also on overground stems of arboreal *Astragalus* spp. (Fabaceae) (see Danzig, 1983) (Fig. 4).

So the question remains: what is the mysterious dye-producing animal recorded by Al-Isfahani and Al-Beruni from willow? Based on the coccidological experience of the first author and on the recent field observations of the second author, we came to the conclusion that the medieval Persian scientists were speaking about felt-scales (family Eriococcidae). Some Asian members of this family in the genera *Acanthococcus* Signoret, 1875 and *Gossyparia* Signoret, 1875 inhabit willows, forming large (if not to say huge) colonies on trunks and branches and clearly demonstrate red colouring matters in their bodies. Below, we shall consider main biological characters of these felt scales and try to understand which of them would be most suitable for receiving dye by traditional methods.

Material and methods

All material is deposited in the Zoological Institute, Russian Academy of Sciences (ZIN RAS) in St Petersburg, Russia.

The numbers with "K" mean unique collecting event and preserved numbers for both fixed acetoethanol material and Canada balsam slides.

Fig. 4. *Porphyrophora epigaea* on arboreal *Astragalus unifoliolatus* (Kazakhstan: Kyzylorda Prov.). **a**, colony of apodal larvae ("cycts") on stem of host plant; **b**, adult female; **c**, apodal larva just before moulting to imago; **d**, apodal larva inside of protective test.

The double numbers without "K" refer to the preserved numbers of the old material deposited in ZIN RAS.

For the method of preparation of the morphological Canada balsam slides see, for example, Gavrilov-Zimin (2018).

The traditional system of scale insect higher taxa (families, subfamilies, tribes) and renovated recently by Danzig & Gavrilov-Zimin (2014) and Gavrilov-Zimin (2018) is used.

Review of the species

Formally, six species of felt-scales were reported by different authors as associated with *Salix* spp. (Salicaceae) in the Asiatic Region and forming more or less dense colonies on their branches and trunks. The study of the available material (cited below) revealed that the females of all six species demonstrate intense scarlet to crimson tint of the body, placed in alkali (Fig. 5) and in

Fig. 5. Adult females of *Gossyparia salicicola*, colouring alkali solution in red tint.

other fluids usually used for the preserving and preparation of scale insects (ethanol, acetic acid, pure water).

Genus ***Gossyparia*** Signoret, 1875

The genus includes two species only: the type species, Holarctic *Gossyparia spuria* (Modeer, 1778), associated mainly with *Ulmus* spp. (Ulmaceae), and Central Asiatic *G. salicicola* Borchsenius, 1949, monophagous of *Salix* spp. (Salicaceae). Formally, *G. spuria* was reported from Azerbaijan as associated with different host plants: *Salix* sp., *Ulmus* sp., *Fraxinus excelsior,* and others (Arutyunova, 1938; Rusanova, 1941), but at that time *G. salicicola* was still undescribed; so, the presence of both species in Azerbaijan is very probable. As for Iran, *G. spuria* was recorded and widely distributed there (Borchsenius, 1949; Moghaddam, 2018 and personal communication), but *G. salicicola* has not been found, although it present in Turkmenistan, where it was collected in Nohur, only 20 km from the border with Iran (material of A.D. Archangelskaya, deposited in the ZIN RAS), so, the future discovery of the species on Iranian territory is very probable.

Gossyparia salicicola Borchsenius, 1949 (Figs 6–9)

Borchsenius, 1949: 328; Matesova, 1967: 1200; Kozár et al., 2013: 262.

Material examined. *Lectotype* and 1 *paralectotype* (on the same slide): females, **Tajikistan**, Hissar Range, near Ziddy Vill., on stem of old willow, 15.VII.1944 (N. Borchsenius leg.).

Other material. **Kazakhstan**: *Kyzylorda Prov.*: K 1486, 15,2 km NE of Kosuyenki Vill., 43°56´12.3´´N, 67°41´09.7´´E, Karatau Range, 390 m altitude, valley of Akuyyk Riv. on branches of *Salix* sp., 25.V.2018 (A.S. Kurochkin leg.), 6 females; K 1493, the same data, but 43°56´06.8´´N, 67°40´50.2´´E, 392 m altitude, 14.V.2018, 2 females; K 1494, the same data, but 43°56´11.9´´N, 67°40´49.5´´E, 391 m altitude, 4 females; *Turkistan Prov.*: K 1496, 11.97 km SE of Tonkeris Vill., 42°0959.25´´N, 70°23´42.08´´E, Western Tian Shan Mts, Ugam Range (1798 m altitude), Sayram-Ugam National Park, valley of Sazanata Riv., on trunk and branches of *Salix* sp., 30.V.2018 (A.S. Kurochkin leg.); *Almaty Prov.*: Alma-Ata, on *Salix*

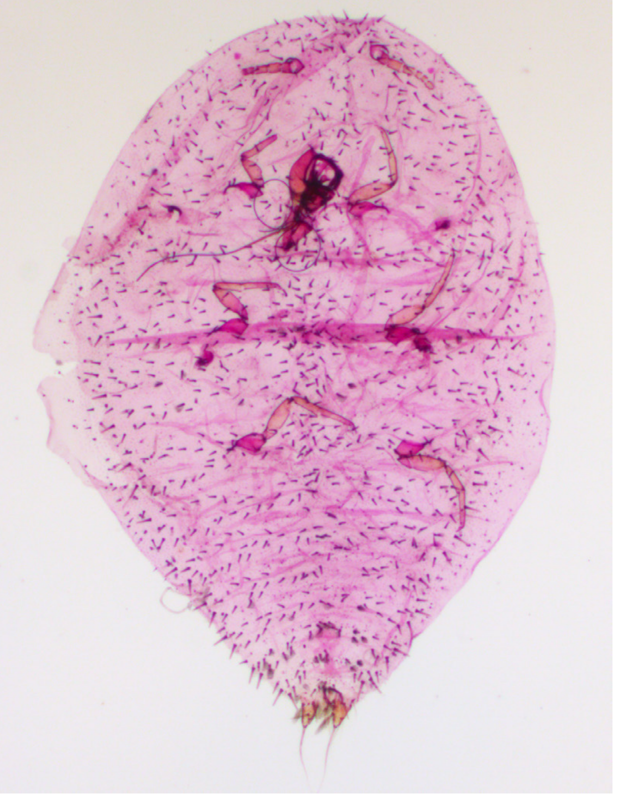

Fig. 6. Adult female of *Gossyparia salicicola*, prepared on slide (Kazakhstan: Kyzylorda Prov.).

fragilis, 16.VI.1937 (E. Samoylovich leg.), 4 females. **Uzbekistan**: *Tashkent Prov.*, on *Salix* sp., VIII.1910 (A.N. Kiritshenko leg.), 3 females; Chimgan, on willow, 25.VII.1911 (P. Borovskoy leg.), 4 females. **Kyrgyzstan**: *Issyk-Kul Prov.*: Karakol, 1910 (D. Pedashchenko leg.), 17 females; *Jalal-Abad Prov.*: Kugat Valley, on *Salix* sp., 27.VII.1937 (N. Borchsenius leg.), 4 females. **Tajikistan**: Hissar Range: Kondara Gorge, on *Salix* sp., 20.VI. 1975 (E. Danzig leg.), 4 females; *Tavildara Distr.*: Tavildara Vill., on willow, VIII.1959 (E.A. Borovkov leg.); *Sughd Prov.*: Istaravshan, 1939 (Bisha leg.), 5 females; "Matga Vill.", on *Salix* sp., 1942 (Timofeeva leg.), 5 females; 3 females; *Khatlon Prov.*: Panj, on trunk of *Salix* sp., 1.VI.1944 (N. Borchsenius leg.); *Kuhistani Badakhshan Autonomous Reg.*: Kalai-Khumb, on *Salix* sp., 27.VIII.1959 (E.A. Borovkov leg.).

Dried colonies of females on pieces of host plants from Kazakhstan, Turkmenistan (Nohur), Uzbekistan, Kyrgyzstan, Tajikistan. Four series of females fixed in aceto-ethanol from Kazakhstan.

Morphological description. *Adult female*. Body egg-shaped, up to 2.5 mm wide, red-brown in life, located inside of grey wax sac which opens on dorsum in ovipositing female (Figs 6–7). Antennae 7-segmented, each about 250 μm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times as long as diameter of anal ring. Multilocular pores absent. Quinquelocular pores, each about 5 μm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral thorax and anterior abdominal sternites. Oval discoidal pores ("cruciform pores" in some authors) each about 3 μm in diameter, forming marginal band on ventral thorax and anterior abdominal sternites. Macrotubular ducts of two sizes, larger ducts, each about

Fig. 7. Colony of adult females of *Gossyparia salicicola* on stem of *Salix* sp., (Kazakhstan: Kyzylorda Prov.) and enlarged illustration of the groups of females.

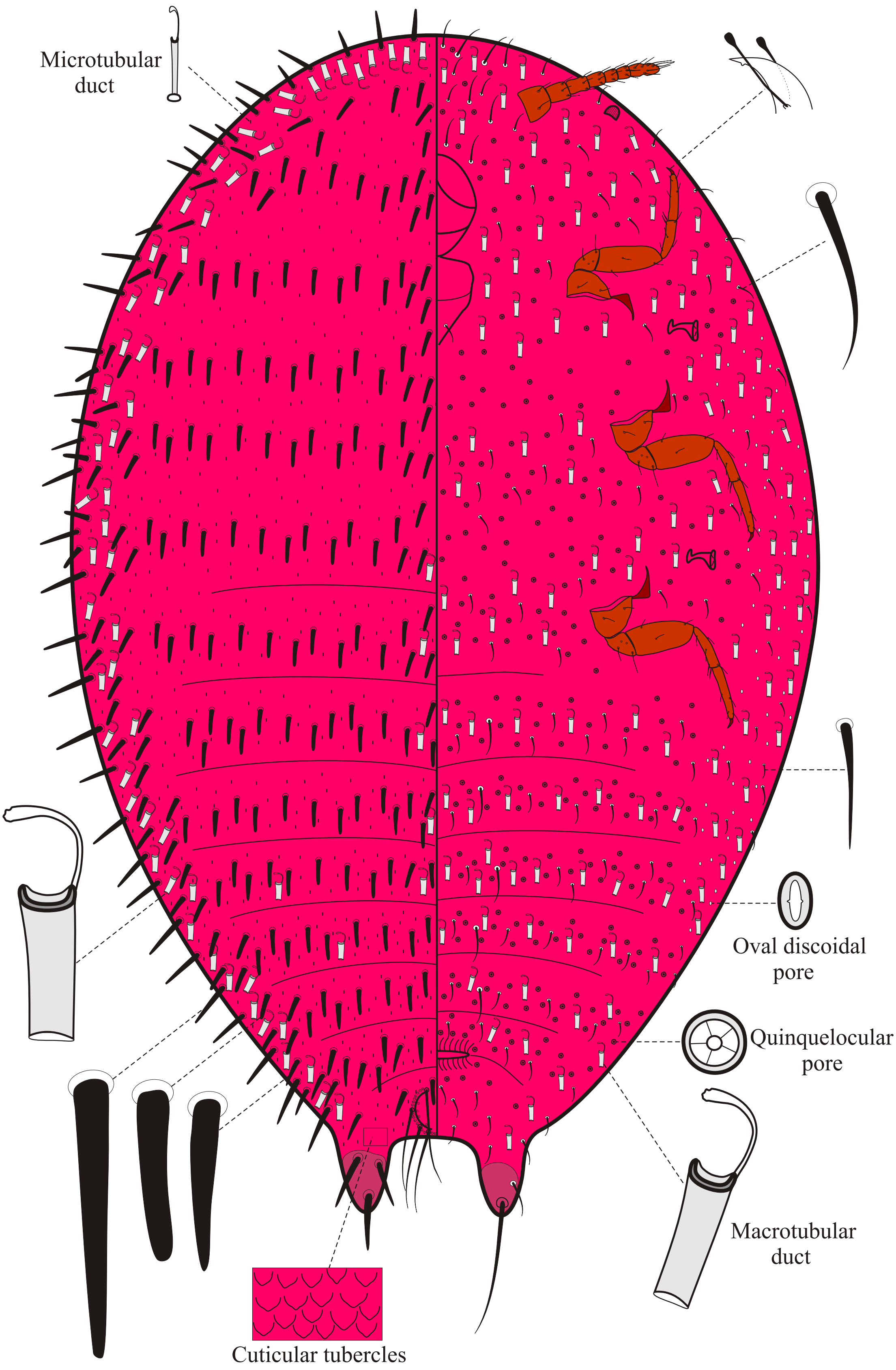

Fig. 8. General morphology of *Gossyparia salicicola* (Kazakhstan: Western Tian Shan Mts).

25–35 µm long and 8 µm wide forming band along midline of thoracic and anterior abdominal tergites and marginal band along all dorsal surface; occasional ducts also present in medial/submedial zone of abdominal tergites; smaller macrotubular ducts, each about 25–30 µm long and 5–7 µm wide, scattered on all ventral surface of body. Microtubular ducts each about 8 µm long and 1 µm wide, scattered on all dorsal surface of body. Conical setae with more or less blunt apices, each about 25–30 µm long, forming transverse rows on all tergites; largest conical setae (each about 55–70 µm long) present forming marginal row with four setae on each side of each tergite (Fig. 8). Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head. Numerous minute cuticular tubercles covering all dorsal surface of body.

Morphology of adult males unknown. Primolarva was described by Borchsenius, 1949.

Ontogenesis and mode of life. As all other felt-scales discussed in this paper, the species has two larval instars before moulting into reproducing neotenic female and four preadult instars (two larval + two nymphal) in male (Fig. 9). For the general review of the scale insect ontogenesis and appropriate terminology see Gavrilov-Zimin (2018). According to Matesova (1967), the species has one generation per year. Ultimolarvae hibernate and then moult to imago in April. In the mid-May, females form wax sacs; complete ovoviviparity takes place and the oviposition starts in mid-June and continues about one month. One female produces 305–418 eggs.

The species is monophagous of *Salix* spp., forming dense colonies on trunks and thick branches (Fig. 7), not infrequently counting thousands of specimens as well as often significantly damaging the host plants (Matesova, 1967).

Distribution. Kazakhstan, Turkmenistan, Uzbekistan, Kyrgyzstan, Tajikistan. Probably, the species is more widely distributed in Western and Central Asia; in particular, its probable presence in Azerbaijan and Iran is discussed above.

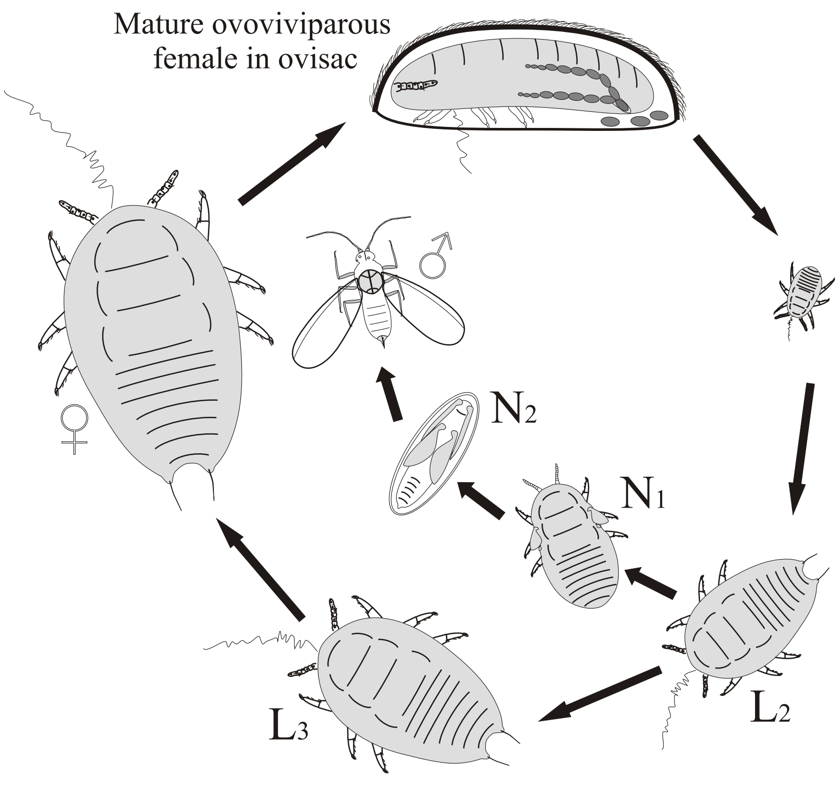

Fig. 9. Generalised scheme of the life cycle of Palaearcic *Gossyparia* – *Acanthococcus* spp. L, larva (without protoptera); N, nymph (with protoptera).

Gossyparia spuria (Modeer, 1778)
(Fig. 10)

Modeer, 1778: 43 (*Coccus*); Cockerell, 1899: 268 (*Gossyparia*); Schrader, 1929: 149 (*Gossyparia*); Borchsenius, 1949: 330 (*Gossyparia*); Schmutterer, 1952: 416 (as *G. ulmi*); Ferris, 1955: 164 (*Eriococcus*); Kosztarab & Kozár, 1988: 289 (*Gossyparia*); Kozár et al., 2013: 262 (*Gossyparia*).

Material examined. **France**: *Ile-de-France*: Mitry-Mory, VIII. 1974 (A. Courtois leg.), 3 females. **Serbia**: Brest, on *Ulmus campestris*, 3.IV.1981 (E. Kozarzhevskaya leg.), 4 females. **Poland**: Slavuta, on *Alnus*, 22.VII.1904 (A. Mordvilko leg.), 6 females. **Ukraine**: Kiev, Botanical Garden of Academy of Sciences, on *Ulmus foliacea*, 1.X.1958 (collector unknown), 5 female larvae; *Sumy Prov.*: on *Ulmus minor*, 28.VI.1960 (E. Tereznikova leg.), 1 female; *Lugansk Prov.*: Novo-Pavlovka Vill., on *Ulmus suberosa*, 20.VI.1962 (E. Tereznikova leg.), 2 females. **Russia**: *Kaliningrad Prov.*: Polessk, on *Ulmus pumila*, 7.VI.1972 (Ivanova leg.), 3 females; *Lipetsk Prov.*: near Manino Vill., on *Ulmus glabra*, 6.VII.1997 (I. Gavrilov leg.), 5 females; *Kursk Prov.*: Tsentralno-Chernozemny Nature Reserve, on *Ulmus* sp., 26.VI.2002 (I. Gavrilov leg.), 2 females; *Volgograd Prov.*: "Gornaia Poliana", 1.VIII.1950 (H. Burnascheva leg.), 1 female; *Krasnodar Terr.*: Betta Vill., on *Ulmus* sp., 2.VII.1990 (E. Danzig leg.), 2 females; Temryuk Distr., on *Ulmus* sp., 27.VI.1990 (E. Danzig leg.), 3 females; *Adygeia Republic:* Kamennomostskaia Settlm., on *Ulmus* sp., 7.VI.1934 (N. Borchsenius leg.), 1 female; *Stavropol Terr.*: Inozemtsevo Settlm., on *Ulmus* sp., 15.VII.1933 (collector unknown), 4 females; Kislovodsk, 23.V.1957 (collector unknown), 2 females. **Crimea**: without locality designation, 1929 (N. Borchsenius leg.), 8 females. **Armenia**: Ayrum, on *Ulmus* sp., 11.VI.1947 (N. Borchsenius leg.), 2 females; Armavir [Oktemberian], on *Ulmus* sp.,14.V.1949 (M. Ter-Grigorian leg.), 2 females; Dzhrvezh, on *Ulmus* sp., 9.X.1956 (V. Trjapitzin leg.), 1 female. **Kazakhstan**: *West-Kazakhstan Prov.*: near Uralsk, on *Ulmus* sp., 16.VI.1950 (Kravets leg.), 9 females. **USA**: *Utah*: Manti, on *Ulmus* sp.,12.VII.1971 (Q.F. Knowlton leg.), 1 female.

Dried colonies of females from: Austria, Italia, Serbia, Ukraine, Russia, Georgia, Armenia, Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan. Three series of females fixed in aceto-ethanol from Bulgaria and European Russia.

Morphological description. Adult female. Body egg-shaped, up to 3 mm wide, red-brown in life, located inside of grey wax sac which opens on dorsum in ovipositing female. Antennae 6–7-segmented, each about 250 μm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times as long as diameter of anal ring. Multilocular pores absent. Quinquelocular pores, each about 5 μm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral thorax and anterior abdominal sternites. Oval discoidal pores ("cruciform pores" in some authors) each about 3 μm in diameter, forming marginal band on ventral thorax and anterior abdominal sternites. Macrotubular ducts of two sizes, larger ducts, each about 20–25 μm long and 8 μm wide forming marginal band along all dorsal surface; occasional ducts also present in submedial zone of abdominal tegrites; smaller macrotubular ducts, each about 15 μm long and 5 μm wide, forming transverse rows on abdominal sternites and scattered in submedial, submarginal and marginal zones of venter. Microtubular ducts each about 8 μm long and 1 μm wide, scattered on all dorsal surface of body. Conical setae with more or less blunt apices, each about 20–25 μm long, forming transverse bands on all tergites; largest conical setae (each about 45–55 μm long) present forming marginal row with four setae on each side of each tergite (Fig. 10). Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head. Numerous minute cuticular tubercles covering all dorsal surface of body.

Morphology of adult males was described by Afifi (1968). Description of larvae see in Herbert (1924) and Dziedzicka (1961).

Ontogenesis and mode of life. The ontogenesis is similar with other species, discussed here (Fig. 9). Only obligatory biparental reproduction is possible (Schrader, 1929). The females are complete ovoviviparous; the oviposited eggs contain fully developed larvae inside. According to Schmutterer (1952) one female produces up to 416 eggs. There is one generation per year overwintering as secundo- or tertiolarvae (Schrader, 1929; Borchsenius, 1949).

Strictly monophagous on *Ulmus* spp. Occasional records of this species from other plants, such as *Fraxinus*, *Alnus*, *Corylus*, *Salix,* and even

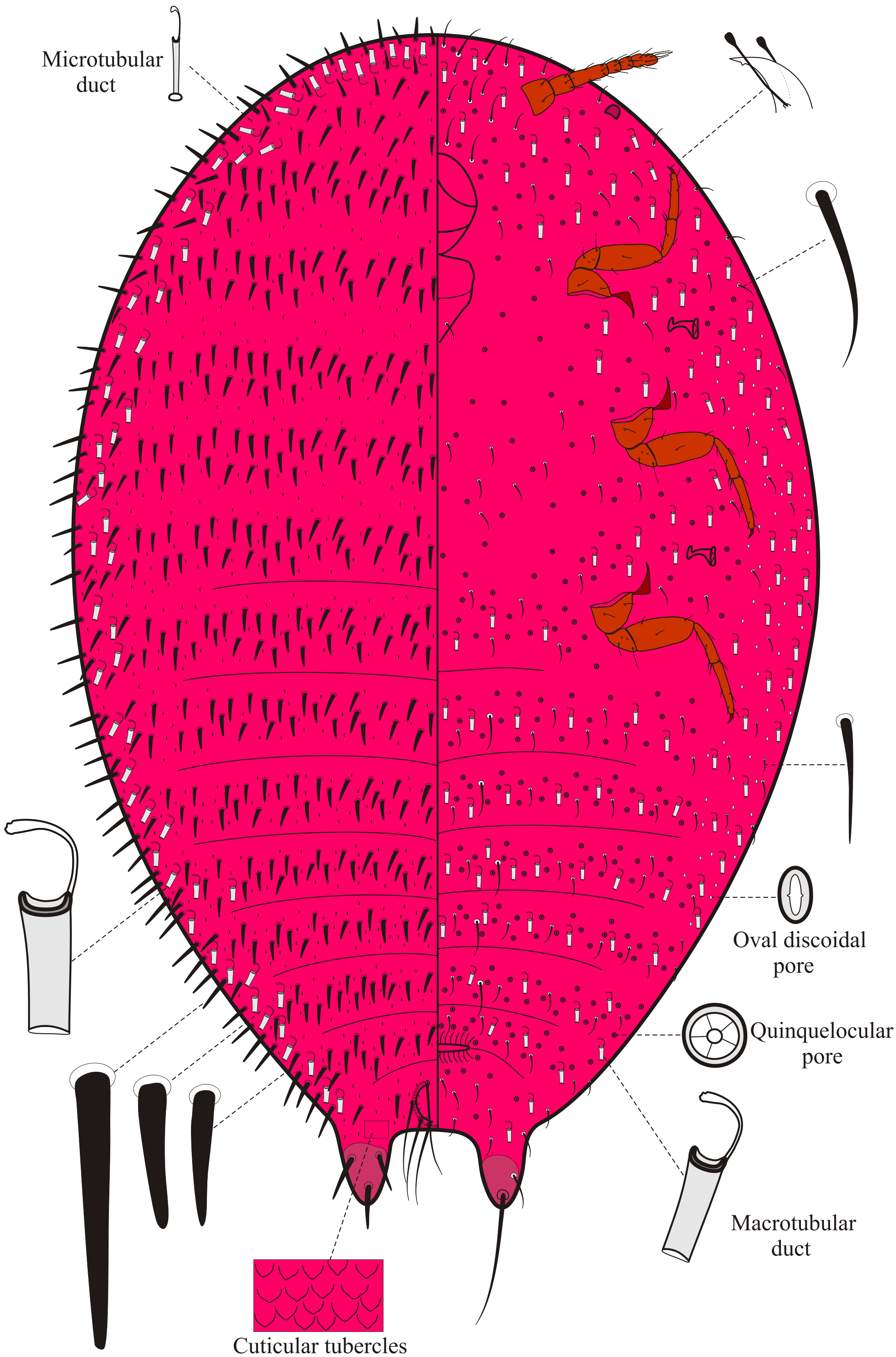

Fig. 10. General morphology of *Gossyparia spuria* (Russia: Lipetsk Prov.)

from grasses (see ScaleNet, 2019), are probably based on misidentification or occasional migration of non-feeding females from their host plants to the nearby plants for oviposition. Sometimes, females form large colonies significantly damaging their host plants.

Distribution. Originally Palaearctic, but now Holarctic species, widely distributed along natural area of *Ulmus* spp. in temperate zone of Northern Hemisphere. The species is very common in Azerbaijan (Arutyunova, 1938; Rusanova, 1941) and Iran (Borchsenius, 1949; Moghaddam, 2018 and personal communication).

Genus ***Acanthococcus*** Signoret, 1875

This huge, world-wide distributed genus comprises about 170 species (ScaleNet, 2019). Most Palaearctic species of the genus inhabit different grasses and perennial herbs; comparatively few species associated with arboreal plants and four of them were formally reported from *Salix* spp.

Acanthococcus aceris Signoret, 1875
(Fig. 11)

Signoret, 1875: 35; Cockerell, 1896: 323 (*Eriococcus*); Borchsenius, 1949: 347 (*Acanthococcus*); Schmutterer, 1952: 416 (*Eriococcus*); Kosztarab & Kozár, 1988: 278 (*Acanthococcus*); Kozár et al., 2013: 262 (*Acanthococcus*).

= *Acanthococcus melnikensis* (Hodgson & Trencheva, 2008: 12, as *Eriococcus*); Gavrilov, 2010: 38 (*Acanthococcus*, synonymisation); Kozár et al., 2013: 134 (unsubstantiated disputing of synonymy).

Material examined. **Germany**: on *Acer campestris* (without other collecting data), 2 females. **Bulgaria**: 10 km S of Kiustendil, on *Quercus* sp., 22.VI.2008 (I. Gavrilov leg.) 1 female. **Poland**: Krakow, on *Quercus rubra*, 29.IX.1966 (E. Danzig leg.), 4 females; unclear locality, on *Acer platanoides*, 15.V.1967 (J. Koteja leg.), 4 females. **Ukraine**: *Zakarpatskaia Prov*.: near Nevitskoe Settlm., on *Acer tatarica*, 16.VI.1956 (N. Borchsenius leg.), 3 females; near Uzhgorod, on *Acer* sp., 18.VI.1956 (N. Borchsenius leg.), 4 females; near Uzhgorod, Latoritsa Riv., 19.VI.1956 (N. Borchsenius leg.), 3 females. **Russia**: *Krasnodar Terr*.: Sochi, Agur Riv. Gorge, on *Acer campestre*, 16.V.2003 (I. Gavrilov leg.); *Karachay-Cherkess Republic*: 10 km S of Arkhyz Vill., 1600 m altitude, on *Acer* sp., 4.VII.1976 (E. Danzig leg.), 2 females; *Dagestan:* 15 km SW of Sergokaly, on *Acer* sp., 16.VII.1983 (E. Danzig leg.), 8 females; *Primorsk Terr*.: Vladivostok, on *Acer mono*, 2.VI.1963 (E. Danzig leg.), 1 female.

Dried colonies of females from Austria, Poland, Ukraine, Russia, and Georgia. Three series of females fixed in ethanol from Bulgaria and Russia (North Caucasus).

Morphological description. Adult female. Body egg-shaped, up to 3 mm long, intense red in life, located inside of white-grey wax sac which totally covers female and oviposited eggs. Antennae 6–7-segmented, each about 300 µm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times as long as diameter of anal ring. Multilocular pores absent. Quinquelocular pores (occasionally 6- or 7-locular pores), each about 5 µm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral head, thorax and anterior abdominal sternites. Oval discoidal pores (“cruciform pores” in some authors) each about 3 µm in diameter, forming marginal band on ventral head, thorax and anterior abdominal sternites. Macrotubular ducts of three sizes: larger ducts, each about 25 µm long and 8 µm wide forming transverse rows on dorsum; mid-sized ducts each about 20 µm long and 5–7 µm wide, forming marginal band on venter and occasionally present in medial-submedial zones of posterior abdominal sternites; smaller macrotubular ducts, each about 15 µm long and 2–3 µm wide, forming transverse rows on II–VII abdominal sternites. Microtubular ducts each about 8 µm long and 1 µm wide, scattered on all dorsal surface of body. Conical setae with more or less blunt apices, each about 15–20 µm long, forming transverse rows or bands on tergites and band along margin of dorsum; largest conical setae (each about 30–50 µm long) forming row (with 3–4 setae on each side of each segment) along body margin. Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head.

Morphology of larvae of both sexes and adult males was described by Hodgson & Trencheva (2008).

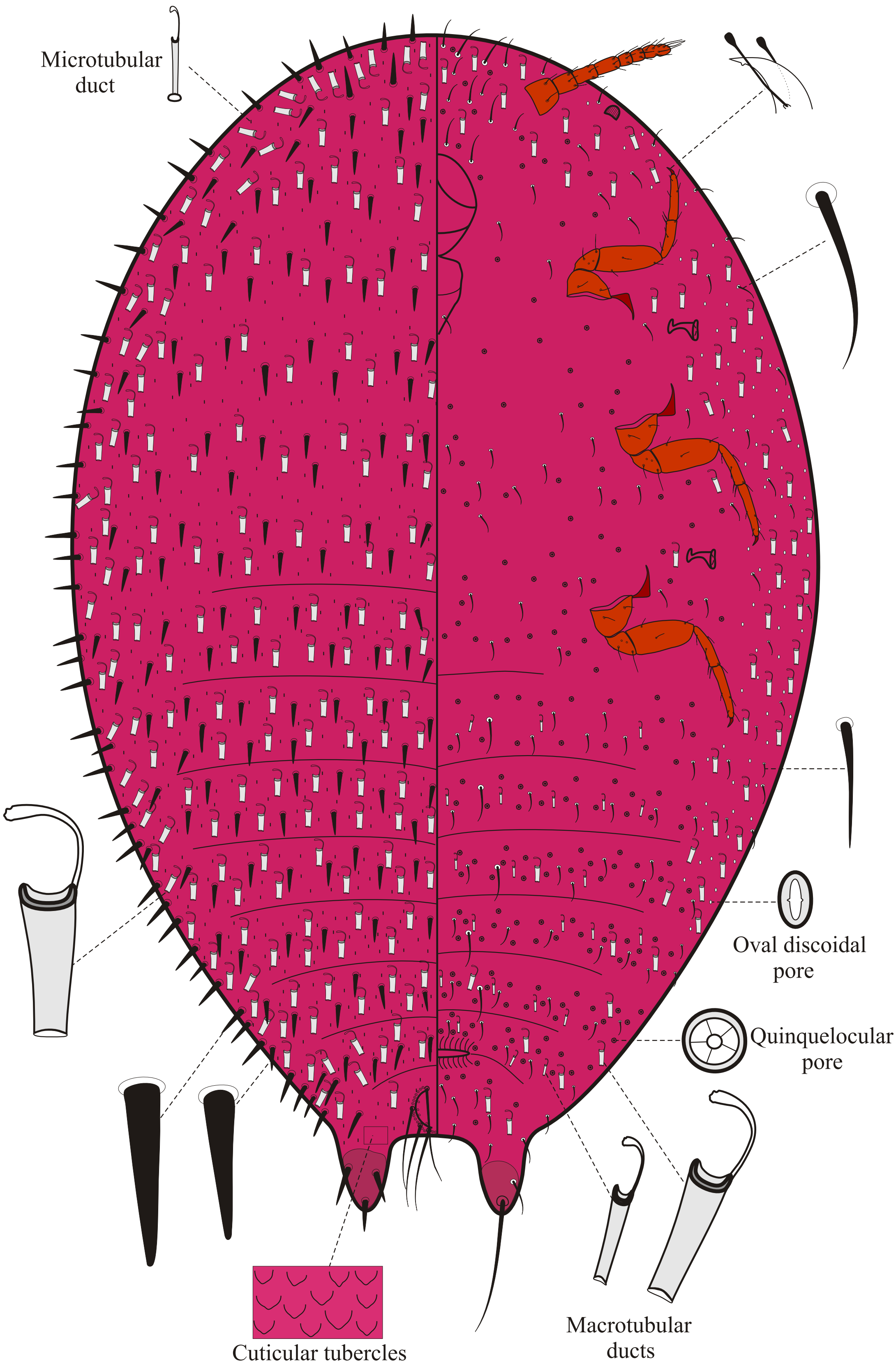

Fig. 11. General morphology of *Acanthococcus aceris* (Russia: Karachay-Cherkess Republic).

Taxonomic notes. Gavrilov (2010: 38) considered in detail the absence of any discrete characters for separation of *A. melnikensis* from well-known and widely distributed *A. aceris*:

"Recently, a new species Eriococcus melnikensis Hodgson & Trencheva (2008), similar to A. aceris, was described from Bulgaria. Unfortunately, the diagnosis of the new species in the original description did not include a comparison of the adult females with those of A. aceris. Moreover, the description of A. aceris in Hodgson & Trencheva (2008) is very brief in comparison with huge description of the new species and was based on the short description by Williams (1985) and several females collected from one population in Padova (Italy). The two characters used by Hodgson & Trencheva (2008) for the separation of these two species were included in the key only (p. 37, l.c.). These two characters were:

1) A. aceris, in contrast to A. (Eriococcus) melnikensis, has setae on antennal segment III. However, there is no enlargement of the antennae in the figure of A. aceris (Fig. 11, page 29, in Hodgson & Trencheva). Based on material preserved in Zoological Institute, St. Petersburg, and on descriptions by Borchsenius (1949) and Williams (1985), A. aceris can have 6- or 7-segmented antennae. When a female has 6 segments, segment III is rather long and bears 2 or 3 setae on its distal part. However, segment III is often more or less divided in two parts and then the new! segment III has no setae, because these remain on the new segment IV. It is well known, that the division or fusion of antennal segments often occurs in scale insects and sometimes a female can have different numbers of segments on two her antennae.

2) A. melnikensis has "ventral medium-sized macrotubular ducts only present submarginally, mainly on head and posterior abdominal segments" in contrast to A. aceris, which has "ventral medium-sized macrotubular ducts present medially on most abdominal segments". However, in the figure (Fig. 7, p. 18, l.c.), only two sizes of ducts are enlarged. Moreover, the description of the new species does not include the size of these ducts; it is written (p. 14) that they are "slightly smaller" than the large ones. In the description of A. aceris (p. 28, l.c.), the sizes of the ducts are not mentioned at all.

In the description of A. aceris by Williams (1985), the medium-sized ducts are "... not numerous [and are present], in more or less single rows on abdominal segments and around submargins to head". So, there is no significant difference in this character even in the descriptions of A. aceris and A. melnikensis. Based on a study of material [in the collection of Zoological Institute] in St Petersburg of A. aceris from different localities, these two species appear to be identical. Unfortunately, this is not surprising because the distribution and number of ducts (or pores) varies very significantly in many scale insect species, especially in widely distributed common species, such as A. aceris Signoret.

Differences were also noted by Hodgson & Trencheva (2008) between first-instar larvae of these two species – in particular, the size and form of the spinose setae. These differences were based on a study of 3 larvae from one population of each species. As the variation of morphological characters in the larvae of scale insects has not been well studied, it is not known what the differences between larvae from different localities, different host plants, etc are likely to be significant. Until there is a clearer understanding of this variation, their taxonomic significance is unknown. Therefore, based on the above mentioned comments, I consider that A. melnikensis is a new junior synonym of A. aceris."

Kozár et al. (2013: 83) tried to dispute this synonymy without providing any counterarguments, but with only the writing of the naive statement: *"there are big differences between first instar nymphs of A. aceris and A. melnikensis which clearly belongs to the Acanthococcus roboris group. On this base we reestablished here A. melnikensis species status"*.

Thus, any reader can clearly see and compare here two different approaches to the discussed taxonomic problem.

Ontogenesis and mode of life. The ontogenesis is similar with other species, discussed here (Fig. 9). The reproduction is bisexual; females lay each 82–378 eggs; primolarvae hatch in about 30–35 days after oviposition (Schmutterer, 1952); overwintering as a secundolarva (Kosztarab & Kozár, 1988).

The species mainly inhabits trunks and branches of *Acer* spp., more rarely *Aesculus* spp., *Quer-*

cus spp., *Fagus* spp. and some other forest trees. The record of willow (*Salix caprea*) as a host plant of this species (Kozár et al., 2013) is probably a mistake, copied from ScaleNet (E. Szita, personal communication). Females usually do not form large colonies or even separate females are located far from each other on the host plant.

Distribution. The species is widely distributed in Europe, Transcaucasia and in the Near East; its presence in Iran (Moghaddam, 2018) was based on a student's note and needs additional checking (M. Moghaddam, personal communication).

Acanthococcus populi Matesova, 1967 (Fig. 12)

Matesova, 1967: 1195; Kozár et al., 2013: 142.

Material examined. *Holotype:* female, **Kazakhstan**: *Alma-Ata Prov.*: Charyn Riv., Sartagoy, on *Populus pruinosa*, 22.VI.1964 (G. Matesova leg.); *paratypes:* female with the same data, but on separate slide; 3 females on 3 slides, with the same data, but road between Chilik Vill. and Ayak-Kaykan Vill., on *Populus diversifolia*, 9.V.1963 (T. Makarov leg.).

Morphological description. *Adult female*. Body egg-shaped, up to 4 mm long, dark-bordeaux in life, located inside of grey wax sac which totally covers female and oviposited eggs. Antennae 7-segmented, each about 250 μm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times as long as diameter of anal ring. Multilocular pores absent. Quinquelocular pores, each about 5 μm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral head, thorax and anterior abdominal sternites. Oval discoidal pores ("cruciform pores" in some authors) each about 3 μm in diameter, forming marginal band on ventral head, thorax and anterior abdominal sternites. Macrotubular ducts slightly differ in size: dorsal ducts, each about 25–30 μm long and 8–10 μm wide forming transverse rows on all tergites, excluding three posterior abdominal tergites, where ducts present along margin only; ventral macrotubular ducts, each about 25 μm long and 7 μm wide, forming transverse rows or bands on abdominal sternites and scattered on thorax and head. Microtubular ducts each about 8 μm long and 1 μm wide, scattered on all dorsal surface of body. Small conical setae with pointed apices, each about 10–15 μm long, forming transverse rows or bands on tergites; large conical setae with blunt apices (each about 30–60 μm long) present along margin of dorsum, 2–4 setae on each margin of each tergite (Fig. 12). Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head. Numerous minute cuticular tubercles covering all dorsal surface of body.

Morphology of adult males and larvae unknown.

Taxonomic note. Kozár et al. (2013) incorrectly placed *A. turanicus* Matesova, 1967 under synonymy of *A. populi* Matesova, 1967. It is a junior synonym of *A. salicis* (Borchsenius, 1938) (see below).

Ontogenesis and mode of life. The ontogenesis is similar with other species, discussed here (Fig. 9). Females form dense colonies on trunks and branches of different *Populus* spp. and *Salix* spp. Oviposition starts in Late June (Matesova, 1967).

Distribution. Kazakhstan (Alma-Ata Prov.), China (Tibet).

Acanthococcus salicis (Borchsenius, 1938) (Figs 13–14)

Borchsenius, 1938: 135 (*Eriococcus*), 1949: 345 (*Acanthococcus*); Danzig, 1980: 208 (lectotype designation); Kozár et al., 2013: 155.

= *A. turanicus* Matesova, 1967: 1197, **syn. nov.**; Kozár et al., 2013: 142 (incorrect placement under synonymy of *A. populi* Matesova, 1967).

Material. *Lectotype* and 2 *paralectotypes* of *A. salicis* (on the same slide): females, **Russia**, *Primorsk Terr.*, Guberovo Station, on willow, 25.VI.1934 (Sh.V. Prun leg.), 3 females; 3 *paralectotypes A. salicis* with the same data, but on 3 separate slides. *Holotype* of *A. turanicus:* female, **Kazakhstan**: *Alma Ata Prov.*, Chulak-Tau Ridge, Kzyl-Aus Gorge, on *Salix wilhelmsiana*, 09.VI.1964 (G. Matesova leg.); 3 *paratypes* of *A. turanicus*: females with the same data, but on 3 separate slides; 3 *paratypes* of *A. turanicus*: females with the same data, but Chilik Vill., on *Salix* sp., 8.V.1963 (T. Makarov leg.), on 2 separate slides; 3 *paratypes* of *A. turanicus*: females with the same data, but Chilik Vill., on *Salix* sp., 3.VII.1965 (G. Matesova leg.), on 3 separate slides; 5 *paratypes* of *A. turanicus*: females,

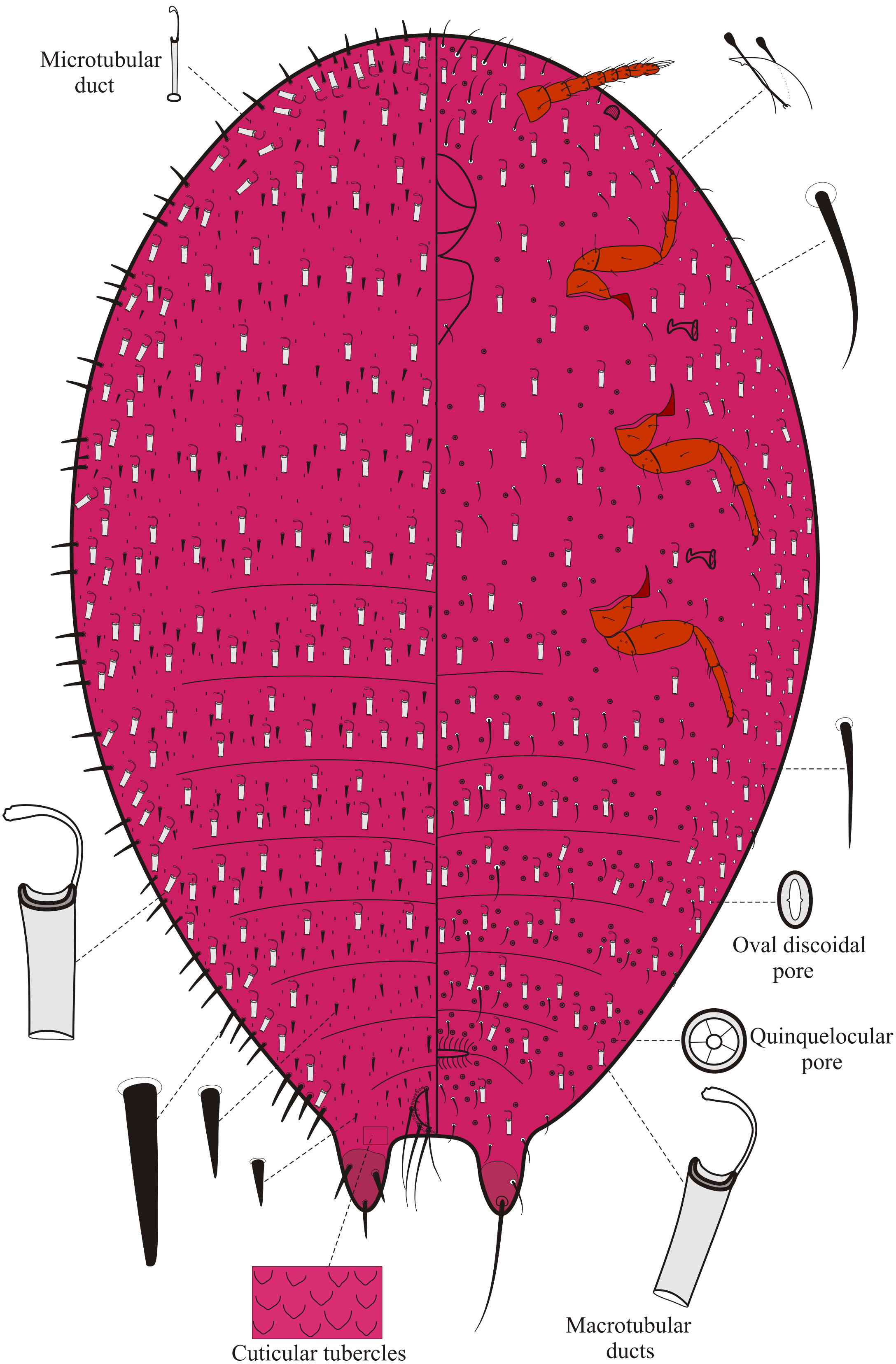

Fig. 12. General morphology of *Acanthococcus populi* (paratype).

Taldy-Kurgan Prov.: Taldy-Kurgan, on 4 slides, on *Salix coerulea*, 17.V.1955 (G. Matesova leg.), on 4 slides; *paratype* of *A. turanicus*: female, **Tajikistan**: Pamir, Bari-Tau Gorge, on *Salix* sp., VIII.1958 (E. Borovkov leg).

Other material. K 1495, **Kazakhstan**: *Kyzylorda Prov.*: 3.35 km SE of Tartogay Vill., 44°24´38.0´´N, 66°16´35.1´´E, on trunk of *Populus euphratica*, 9.V. 2018 (A.S. Kurochkin leg.), 2 females. Series of females with the same collecting data in acetoethanol. **Russia**: *Khabarovsk Terr.*: Khabarovsk Distr., on *Salix* sp., 27.V.1959 (collector unknown), 3 females; *Primorsk Terr.*: Ussuriysk, valley of Komarovka [Suputinka] Riv., on *Salix* sp., 11.VI.1963 (E. Danzig leg.), 2 females; Ussuriysk, on *Salix* sp., 27.V.1950 (B. Chumakova leg.), 2 females; Guberovo Station, on willow, 25.VI.1934 (Sh.V. Prun leg.), 2 females.

Dried colonies of females from Russia. Three series of females in ethanol from Russia. One series of females in acetoethanol from Kazakhstan.

Morphological description. *Adult female*. Body egg-shaped, up to 4 mm long, dark-bordeaux in life, located inside of yellow-white wax sac, which totally covers female and oviposited eggs. Antennae 7-segmented, each about 250 µm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times as long as diameter of anal ring. Multilocular pores absent. Quinquelocular pores, each about 5 µm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral surface of head, thorax and anterior abdominal sternites. Oval discoidal pores (“cruciform pores” in some authors) each about 3 µm in diameter, forming

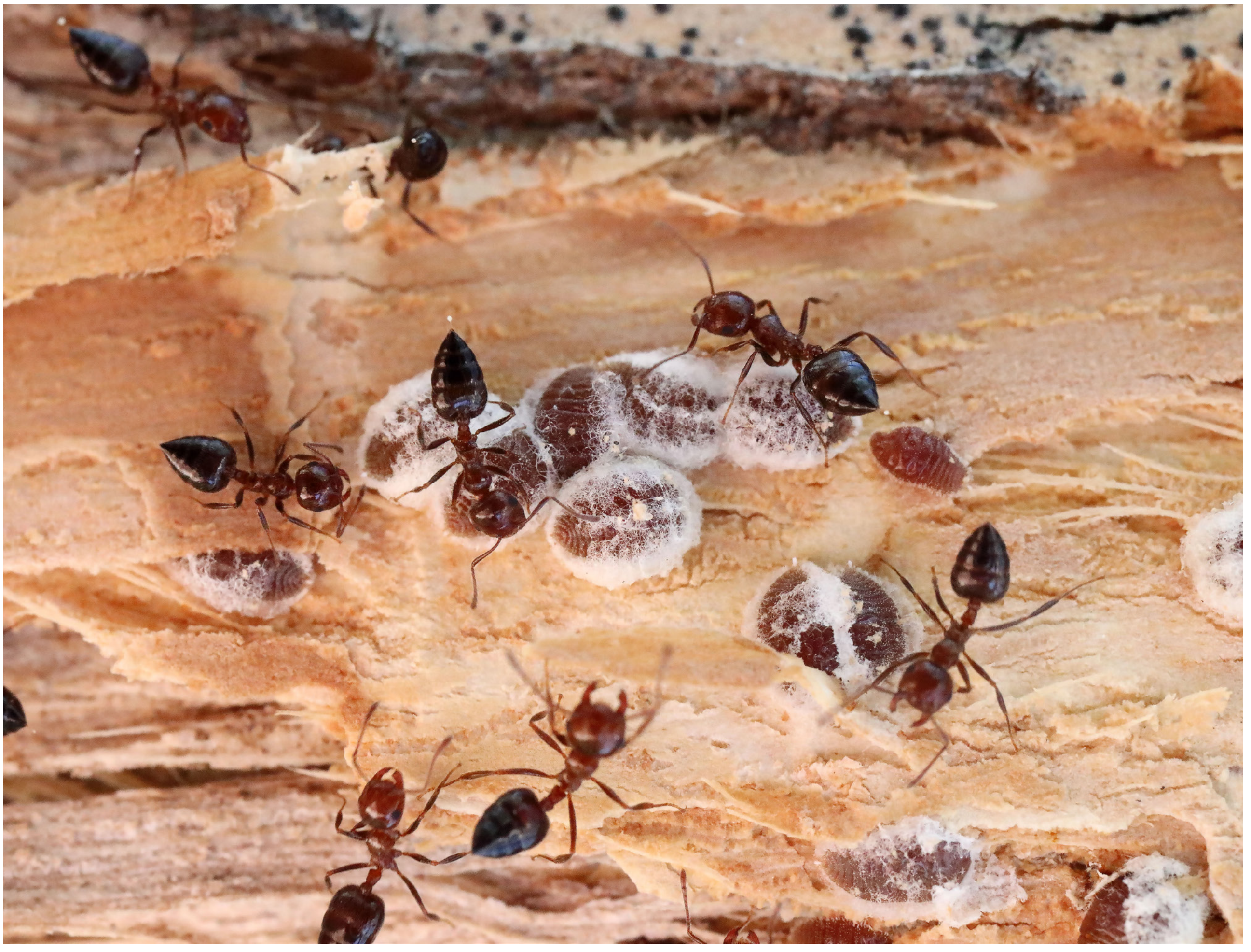

Fig. 13. Colony of young adult females and larvae of *Acanthococcus salicis* on stem of *Populus euphratica*, attended by ants (Kazakhstan: Kyzylorda Prov.).

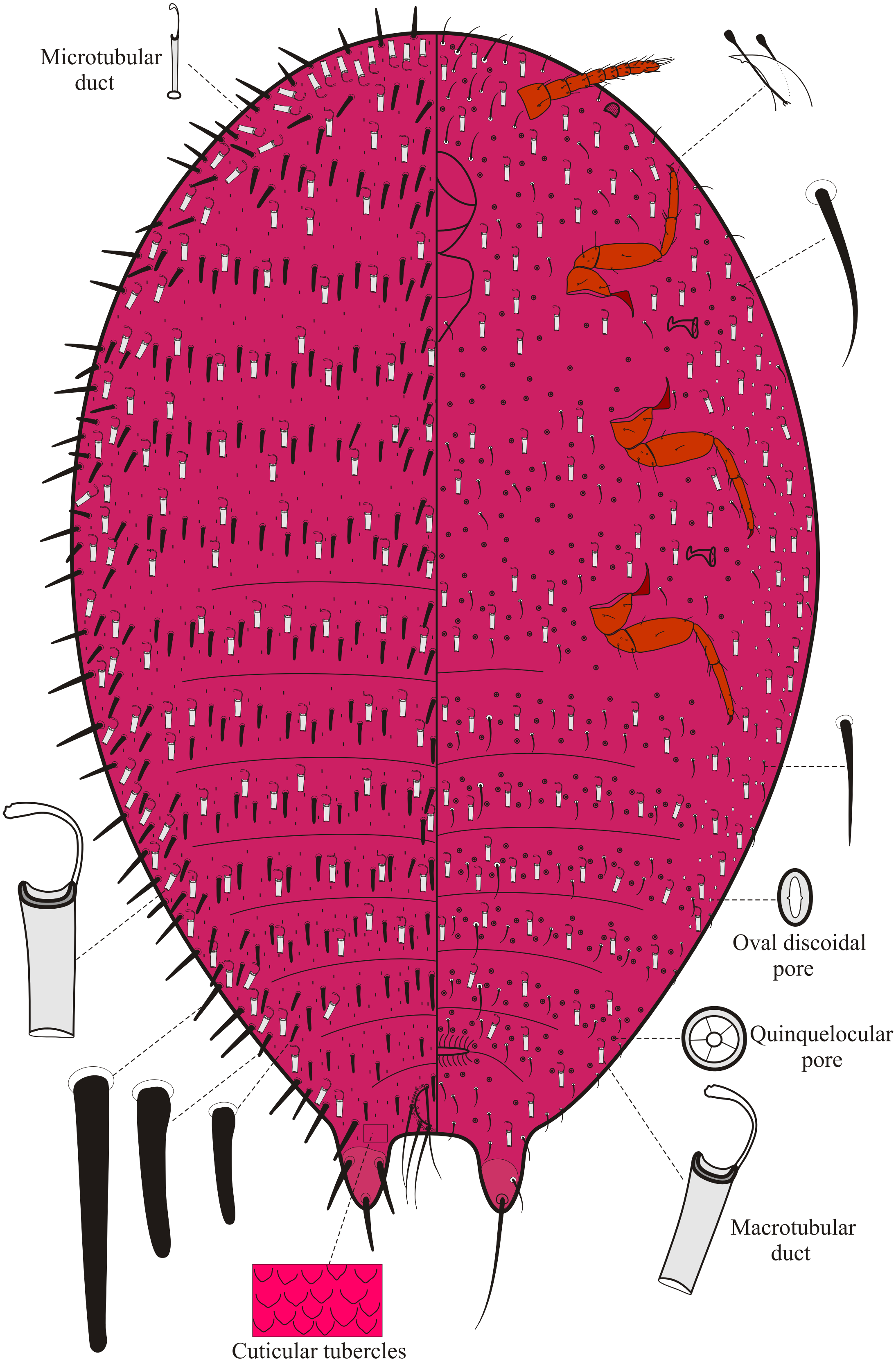

Fig. 14. General morphology of *Acanthococcus salicis* (lectotype).

marginal band on ventral thorax and anterior abdominal sternites. Macrotubular ducts slightly differ in size: dorsal ducts, each about 20–25 µm long and 5–6 µm wide forming transverse rows and bands on tergites, excluding three posterior abdominal tergites, where ducts usually present in marginal zone only; ventral macrotubular ducts, each about 20 µm long and 5 µm wide, forming transverse rows or bands on abdominal sternites and scattered on thorax and head. Microtubular ducts each about 8 µm long and 1 µm wide, scattered on all dorsal surface of body. All conical setae more or less cylindrical, with blunt or slightly clavate apices; smaller conical setae, each about 20–25 µm long, forming transverse bands on all tergites; large conical setae (each about 30–50 µm long) present along margin of dorsum, 2–4 setae on each margin of each tergite (Fig. 14) and along dorsal midline. Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head. Numerous minute cuticular tubercles covering all dorsal surface of body.

Morphology of adult males and larvae unknown.

Taxonomic note. Kozár et al. (2013: 155) provided partially incorrect information on the types: "Russia (Siberia, Guberoro), on *Salix* sp., 25.VI.1934, by S.V. Brown" (see the correct data above). Probably, this information was simply copied from on-line database ScaleNet, which, unfortunately, is full of such kind of mistakes. Also, Kozár et al. (2013) incorrectly placed *A. turanicus* Matesova, 1967 under synonymy of *A. populi* Matesova, 1967, probably in view of an occasional mistake during combining different species information in the book. These species clearly differ from each other in size and form of conical setae (see Key in Matesova, 1967 and new Key below). In reality, *A. turanicus* is a junior synonym of *A. salicis* (Borchsenius, 1938). The last two nominal species were not compared previously.

Ontogenesis and mode of life. The ontogenesis is similar with other species, discussed here (Fig. 9). Females form colonies on branches of different *Salix* spp. Here it is also noted from *Populus euphratica* (Salicaceae).

Ovoviviparous species with oviposition during June (Matesova, 1967; Danzig, 1980).

Distribution. Turkey, Kazakhstan, Russia (Far East), Mongolia, China.

Acanthococcus spiraeae Borchsenius, 1949 (Figs 15–18)

Borchsenius, 1949: 348. Kozár et al., 2013: 163.
= *Acanthococcus altaicus* Matesova, 1967: 1193, **syn. nov.** Kozár et al., 2013: 87.

Material examined. *Lectotype* and 2 *paralectotypes* (on the same slide) of *A. spiraeae*: females, **Georgia**: Tbilisi, on twigs of *Spirea hypericifolia*, 17.VII.1934, (N. Borchsenius leg.). *Holotype* and 5 *paratypes* (all on separate slides) of *A. altaicus*: females, **Kazakhstan**: *Eastern Kazakhstan Prov.*: Ubinski Ridge near Orlovka Vill., on *Salix* sp., 08.VI.1961 (G. Matesova & T. Makarov leg.).

Other material. **Russia**: *Irkutsk Prov.*: Bolshoy Lug Settlm., moss bog, on *Salix* sp., 16.VII.1970, 3 females, on *Betula* sp. 10.VII.1970, 4 females, on *Betula nana*, 20.VII.1970, 2 females (E. Danzig leg.); Kyngorgi Riv. valley, 7 km upstream from Arshan, on *Salix* sp., 26.VII.1970 (E. Danzig leg.), 5 females; *Yakutia*: Vitim Settlm., 25.VI.1961 (collector unknown), 2 females;

Fig. 15. Young females of *Acanthococcus spiraeae* on twig of *Spiraea hypericifolia* (Kazakhstan: Turkestan Prov.).

a b

Fig. 16. Females of *Acanthococcus spiraeae* on twig of *Spiraea hypericifolia* (Kazakhstan: Turkestan Prov.). **a**, older females inside of wax ovisacs; **b**, crushed female demonstrating purple pigment of body.

Verkhoiansk, on *Spiraea salicifolia*, 24.VII.1974 (E. Danzig leg.), 2 females; Khaptagay Settlm., on *Spiraea salicifolia*, 28,29.VI.1974, 2.VII.1974 (E. Danzig leg.), 10 females. **Georgia**: Tbilisi, 17.VII.1934 (N. Borchsenius leg.), 3 females. **Kazakhstan**: *Alma-Ata Prov.*: near lake Issyk, on *Spiraea* sp., 12.VII.1936 (collector unknown), 3 females; Talgar Reserve, on *Spiraea* sp.,12.IX.1969 (E. Danzig leg.), 5 females; *Semipalatinsk Prov.*: near Kenderlyk, on *Spiraea* sp., 5.VI.1954 (Matesova leg.), 4 females; *Kostanay Prov.*: 10 km N of Nikitinka, on *Spiraea* sp., 7.VI.1971 (E. Danzig leg.), 3 females; K 1497, *Turkestan Prov.*, 42°10´00.2´´N, 70°24´58.8´´E, Western Tian Shan Mts, Ugam Range (1940 m altitude), Sayram-Ugam National Park, valley of Sazanata Riv., on branches and twigs of *Spiraea hypericifolia*, 31.V.2018 (A.S Kurochkin leg.), 4 females; K 1500, the same data, but 42°09´59.5´´N, 70°25´07.9´´E, 1946 m altitude, 2 females. **Uzbekistan**: 5 km N Khumsan, 14.V.1963 (E. Sugoniaev leg.), 3 females; 20 km N Khumsan, 18.V.1963 (E. Sugoniaev leg.), 1 female. **Mongolia**: 10 km W Tariat, 22.VI.1975 (E. Sugoniaev leg.), 3 females.

Two series of females in ethanol from Russia and Georgia. Two large series of females from Kazakhstan (K 1497 and K 1500) fixed in aceto-ethanol. Dried colonies of females from: Russia, Kazakhstan, Uzbekistan, and Mongolia.

Morphological description. *Adult female*. Body egg-shaped, up to 2.5 mm long, intense red in life, located inside of grey wax sac which totally covers female and oviposited eggs. Antennae 6–7-segmented, each about 250 μm long. Legs with all segments normally developed, without translucent pores; claw with denticle; claw digitules with clavate apices. Anal apparatus with outer row of spinulae, incomplete inner row of pores and eight long setae, each about two times s long

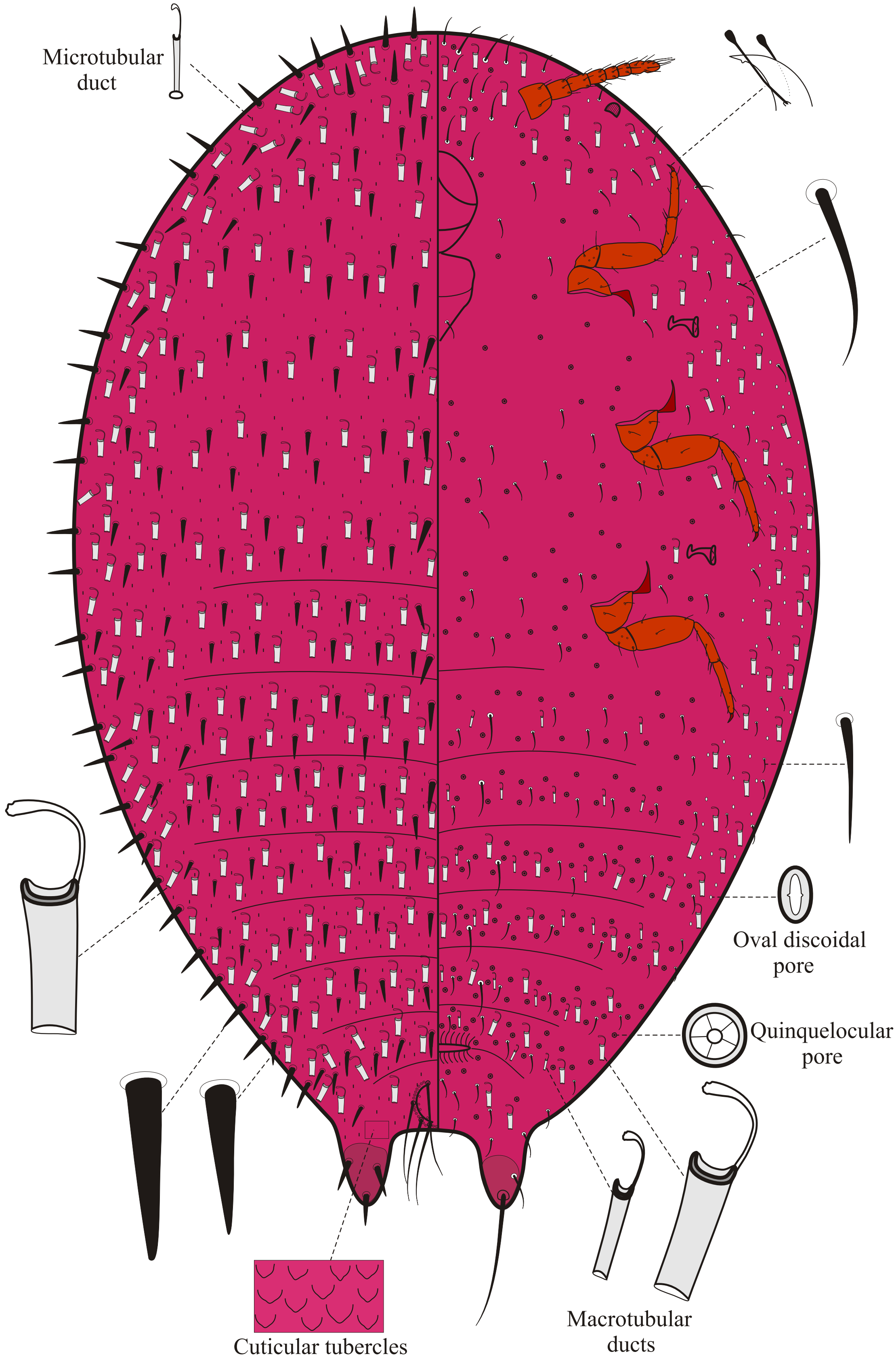

Fig. 17. General morphology of *Acanthococcus spiraeae* (Kazakhstan: Turkestan Prov.).

as diameter of anal ring. Multilocular pores absent. Quinquelocular pores, each about 5 µm in diameter, scattered on all ventral surface of body, excluding marginal zone of ventral head, thorax and anterior abdominal sternites. Oval discoidal pores ("cruciform pores" in some authors) each about 3 µm in diameter, forming marginal band on ventral head, thorax and anterior abdominal sternites. Macrotubular ducts of three sizes: larger ducts, each about 25 µm long and 8 µm wide forming transverse rows on dorsum; mid-sized ducts each about 25 µm long and 5–7 µm wide, forming marginal band on venter and transverse rows on five posterior abdominal sternites; smaller macrotubular ducts, each about 15 µm long and 2–3 µm wide, forming transverse rows on II–VII abdominal sternites. Microtubular ducts each about 8 µm long and 1 µm wide, scattered on all dorsal surface of body. Conical setae with more or less pointed apices, each about 15–30 µm long, forming transverse rows or bands on tergites and band along margin of dorsum; largest conical setae (each about 40–50 µm long) present pairwise on each margin of each tergite and along midline (Fig. 17). Flagellate setae of different sizes forming transverse rows on abdominal sternites and sparsely present on ventral surface of thorax and head. Numerous minute cuticular tubercles covering all dorsal surface of body.

Morphology of adult males and larvae unknown.

Taxonomic note. Matesova (1967) did not compare *A. altaicus* with earlier described *A. spiraeae*. During our study of the type material of both these nominal species and numerous additional specimens, collected in different regions and iden-

Fig. 18. Collecting locality of *Acanthococcus spiraeae* (Kazakhstan: Turkestan Prov.: Western Tian Shan Mts., Ugam Range, about 1940 m altitude).

tified by previous authors as *A. altaicus* or *A. spiraeae,* we were unable to find any distinct differences between them. In the result we consider *A. altaicus* as a **new junior synonym** of *A. spiraeae.*

Kozár et al. (2013) incorrectly figured macrotubular ducts in medial/submedial zone of thoracic sternites of *A. altaicus*, whereas the absence of these ducts in this zone is one of the diagnostic characters noted in the original description of *A. altaicus.* The ducts in this zone are absent in all type and non-type specimens of *A. spiraeae* (=*A. altaicus*), studied by us.

Ontogenesis and mode of life. The ontogenesis is similar with other species, discussed here (Fig. 9). One female produces 76–116 eggs in late May-early June (Matesova, 1967 and present data).

Females and larvae inhabiting branches and stems (Figs 15–16) of different species of *Spiraea*, *Betula*, *Salix*. On *Salix* spp. in Kazakhstan females form large dense colonies.

Matesova (1967) reported a peculiar symbiosis of *Acanthococcus spiraeae* (=*A. altaicus*) with the aphid *Phylloxerina salicis* (Lichtenstein, 1884) (Aphidinea: Adelgoidea: Phylloxeridae). The aphid female is about three times smaller than the female of *A. spiraeae* and located under the last inside of the shared wax ovisac. Phenology of both the aphid and the felt scale is very similar and even the oviposition is started in the same time; the eggs of the aphid are smaller and lie in the was sac just under the eggs of the felt scale. Sometimes two aphid females may present in one ovisac with a female of *A. spiraeae*, whereas about 19 % of the felt scale females in the population lack symbiotic aphids at all.

Distribution. Georgia, Kazakhstan, Uzbekistan, Russia (Irkutsk Prov., Yakutia), (Turkestan Prov., Eastern Kazakhstan Prov.), and Mongolia.

Summarising all available data on the six species of felt scales reviewed above we can presume that three of them, ***Gossyparia salicicola***, ***Acanthococcus salicis*** and ***A. spiraeae*** could be the most probable source of red dye, associated with *Salix* spp. in Western and Central Asia. Three other species are less suitable due to different reasons. Both *Acanthococcus aceris* and *Gossyparia spuria* associated primary with other host plants and the occasional reports from *Salix* spp. are dubious; moreover, *Acanthococcus aceris* usually does not form large female colonies, which are suitable for applied collecting. The last species, *A. populi*, has a very local distribution in Alma-Ata Province, Eastern Kazakhstan. The only other record of this species from the other locality, Tibet (Tang & Hao, 1995), needs additional verification, because at the time of that publication, there was no general review or key for Asiatic *Acanthococcus* spp. available, and it was easy to mix *A. populi* with other similar species during identification.

Key to Asiatic Eriococcidae, formally noted from *Salix* spp.

1(8). Dorsal tubular ducts numerous, forming transverse rows on segments of body. Ovipositing female located inside of wax sac which totally covers it and oviposited eggs . . . . ***Acanthococcus*** spp.

2(5). Ventral macrotubular ducts present in medial/submedial zone of thorax. Macrotubular ducts on abdominal sternites of approximately one size.

3(4). Medial/submedial dorsal conical setae tapered, all several times smaller than marginal setae . . . . . ***A. populi***

4(3). Medial/submedial dorsal conical setae cylindrical, with blunt or slightly clavate apices; some of them similar in size with marginal setae . . . . ***A. salicis***

5(2). Ventral macrotubular ducts absent in medial/submedial zone of thorax. Macrotubular ducts on abdominal sternites of two clearly defined sizes.

6(7). Marginal row of conical setae including 2 large setae on each side of each abdominal segment . . . ***A. spiraeae***

7(6). Marginal row of conical setae including 2–3 large setae and 1–2 mid-sized setae on each side of each abdominal segment . . . . ***A. aceris***

8(1). Dorsal tubular ducts few, present along body margin and occasionally along midline. Ovipositing female located inside of wax sac which open on dorsum . . . . genus ***Gossyparia***

9(10). Marginal row of conical setae including 3–4 large setae on each side of each abdominal segment. Macrotubular ducts absent in medial zone of dorsum . . . . ***G. spuria***

10(9). Marginal row of conical setae including 2 large setae on each side of each abdominal segment. Macrotubular ducts present along midline of thoracic and anterior abdominal tergites . . . . ***G. salicicola***

Pigments of felt scale-insects and some related groups

The available chemical analyses of Eriococcidae are limited to two very similar Australasian species of *Acanthococcus*, associated with *Eucalyptus* spp.: *Acanthococcus confusus* (Maskell, 1892) and *A. coriaceus* (Maskell, 1893) (Chan & Crow, 1966; Banks & Cameron, 1970; Banks et al., 1976a). Those studies revealed that the pigments of both insects are neither carminic nor similar acids, but different polyhydroxyanthraquinones, based on emodin, the chemical substance known also in some plants (for example, *Rheum* spp., *Rhamnus* spp.) and fungi (for example, *Aspergillus* spp., *Pestalotiopsis* spp.). In particular, *A. coriaceus* (Fig. 19) has a group of seven polyhydroxyanthraquinones, which cause intense scarlet to crimson tint of the insect body, placed in alkali (Banks & Cameron, 1970; Banks et al., 1976; Gullan & Vranjic, 1991). Unfortunately, there are no any chemical data on other felt scales, including all Palaearctic species. It could be noted that some chemically unstudied species of Eriococcidae, as well as some genera/species of the ancestral family Pseudococcidae (mealybugs), demonstrate different colouring matters after crushing of their bodies in alkali, ethanol, water, and other substances (Ferris, 1950; McKenzie, 1967; Williams, 2004; Gullan & Vranjic, 1991; Danzig & Gavrilov-Zimin, 2014). For example, intense red tint is demonstrated by some species of the type genus of felt scales, *Eriococcus buxi* (Boyer de Fonscolombe, 1834) and *E. williamsi* Danzig, 1987, both connected with *Buxus* spp. (Buxaceae) Some species of "legless mealybugs", *Antonina* Signoret, 1875 and related genera, inhabiting mainly different bamboos (Poaceae), also have red tint of body content. At the same time, such mealybugs as *Amonosterium* spp., *Melanococcus* spp., *Nipaeo-*

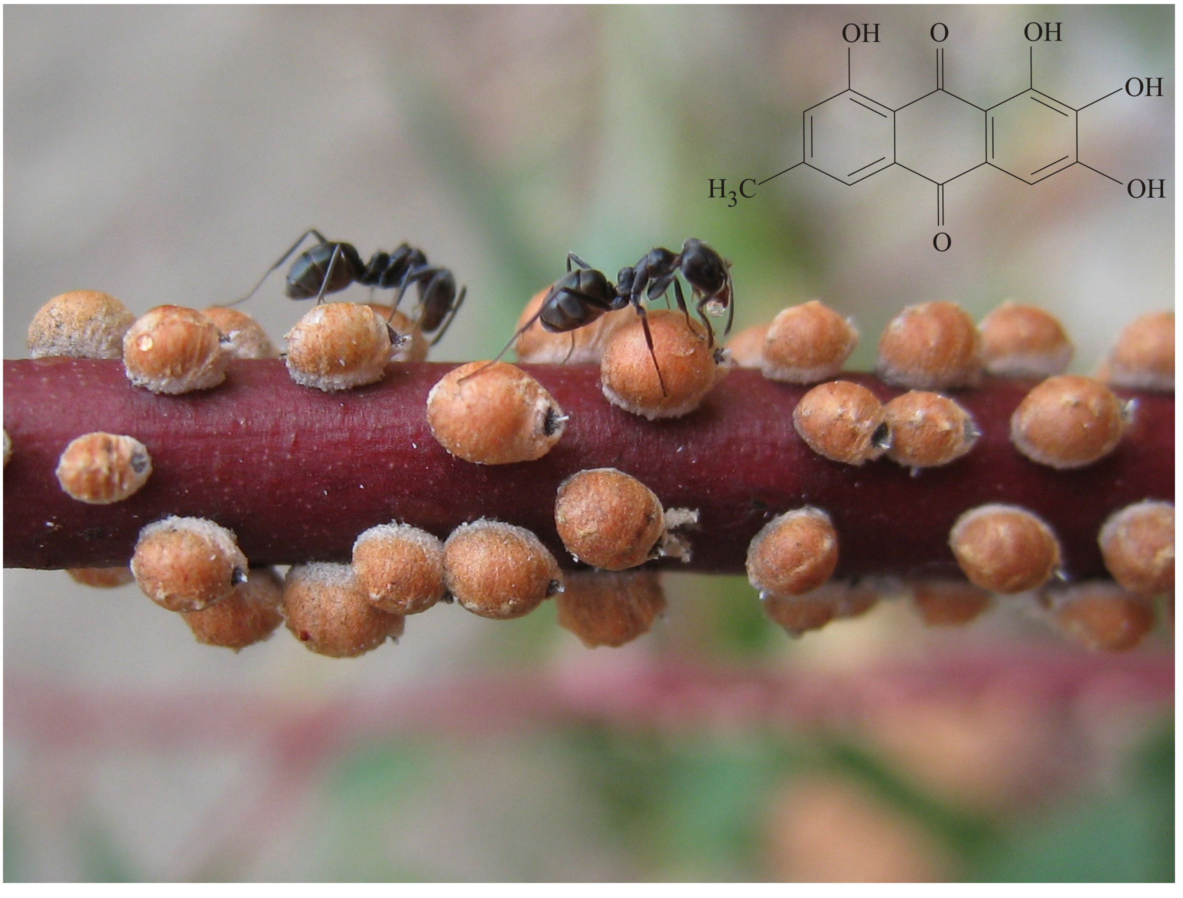

Fig 19. *Acanthococcus coriaceus*, adult females on the twig of eucalypt, photo of John Tann, NSW Australia (see Acknowledgements) and formula of one of the pigments, 1,2,3,8-tetrahydroxy-6-methylanthraquinon (refigured here according to the data of Chan & Crow, 1966 and Banks et al.,1976a).

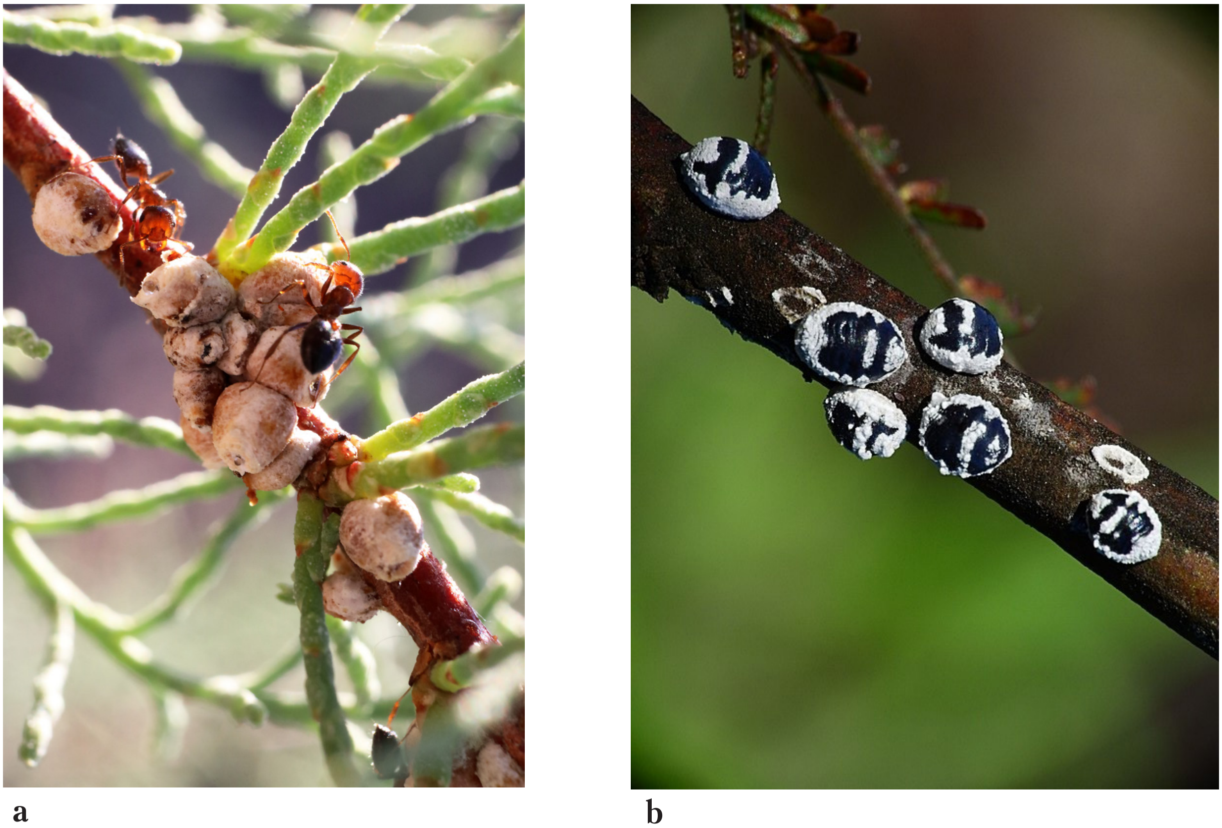

Fig. 20. "Blue-black mealybugs". **a**, *Trabutina mannipara* (Hemprish et Ehrenberg, 1829), original photo, adult females in wax sacs on twig of *Tamarix* sp., Kazakhstan: Kyzylorda Prov.; **b**, *Melanococcus albizziae* (Maskell, 1892), adult females on twig of *Acacia mearnsii*, photo of Max Campbell, NSW Australia (see Acknowledgements).

coccus spp., *Trabutina* spp. (Fig. 20), *Atrococcus* spp., associated with different herbaceous and arboreal host-plants, demonstrate dark-purple, blue-black, or blue-green colour of body content in life and/or after placing them in ethanol or alkali. The available chemical studies of mealybug pigments in *Melanococcus albizziae* (Maskell, 1892) (Fig. 20) and *Nipaeococcus aurilanatus* (Maskell, 1889) revealed different anthraquinones (similar in general with those in other scale insects) and also hypericin (Fig. 21) with allied pigments (Banks et al., 1976b). It is interesting to note that the intensive red pigment hypericin is also well-known as a component of St John's wort, *Hypericum* spp. (Hypericaceae) (Brockmann & Sanne, 1957). On the other hand, it seems that the majority of felt scales and mealybugs have pale yellow or white body in life as well as during preparation in ethanol, acetic acid, alkali, etc. The further comprehensive biochemical studies of Eriococcidae and Pseudococcidae as well as other poorly-investigated scale-insect families will definitely lead to discovery of significantly new information on pigments and their possible involvement in the production of natural dyes.

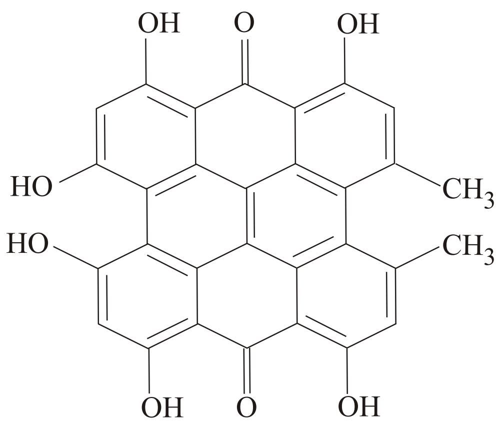

Fig. 21. Hypericin, formula refigured here according to the data of Brockmann & Sanne (1957) and Banks et al. (1976b).

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