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# Occurrence and spread of *Ceroplastes cirripediformis* Comstock (Hemiptera: Coccomorpha: Coccidae) in India

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## Abstract

The notoriously destructive and invasive soft scale, *Ceroplastes cirripediformis* Comstock (Hemiptera: Coccomorpha: Coccidae), is recorded for the first time from India. The scale is redescribed to facilitate its identification and information on its host range, natural enemies and distribution is provided. An identification key to the Indian species in this genus is given. Management options in the event of an outbreak are discussed briefly. The establishment of this scale insect warrants special attention in India as it is a potentially damaging plant pest and has a broad host range across many plant families.

**Key words**: introduction, invasive species, plant pest, natural enemies

## Introduction

Scale insects are potentially invasive species, despite their limited mobility, mainly because of the growing global transport of timber, live plants and fruits; this is an effective dispersal method for these sedentary insects (Ouvrard *et al*. 2013).

*Ceroplastes* Gray is a large genus with 144 species known worldwide (García Morales *et al*. 2016); numerous species in this genus are major polyphagous pests (Ouvrard *et al*. 2013). At present, 11 species of *Ceroplastes* are known from India, of which *C. ajmerensis* (Avasthi & Shafee), *C. alami* Avasthi & Shafee and *C. stipulaeformis* (Haworth) are endemic to the subcontinent (García Morales *et al*. 2016).

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The barnacle scale, *C. cirripediformis* Comstock, is an important pest of *Citrus* and many ornamentals (Gimpel *et al*. 1974; Kosztarab, 1996). Although it has not been recorded as a serious pest of commercial crops in California, it is an occasional pest of ornamental *Gardenia* plants there (Gill, 1988). It is an occasional serious pest in Mexico, the West Indies and other parts of the Caribbean (Bartlett, 1978), and is known from the Nearctic, Neotropical, Palaearctic, Indo-Australian and Oriental regions. The most recent reports are from China (Li *et al*. 2018). The species is of quarantine significance and was intercepted 26 times on a variety of hosts at U.S. ports-of-entry between 1995 and 2012, on plant parts originating from China, Colombia, Hawaii, Jamaica, Mexico, Montserrat, Nicaragua, Puerto Rico and Tonga (Miller *et al*. 2014).

Here we report the first detection and spread of *C. cirripediformis* in India. It was designated as an invasive scale by the Center for Agriculture and Bioscience International in 2017 (Wang *et al*. 2020). In life, it is similar to other *Ceroplastes* species, so a detailed description of the live insect and illustrations of its diagnostic characters are provided to facilitate identification.

## Materials and methods

Surveys have been conducted across India since 2009 to collect scale insects and their natural enemies. Since 2012, scale insect samples from different State Agricultural Universities and ICAR (Indian Council of Agricultural Research, New Delhi) institutes have been received by the senior author for identification. A total of 426 specimens were examined from seven states *viz*., Karnataka (220), Tamil Nadu (36), Maharashtra (83), Gujarat (5), Kerala (56), Himachal Pradesh (5) and Uttar Pradesh (21); these figures include personally collected material as well as specimens received for identification. During collection, plant parts infested with scale insect colonies were cut with secateurs and kept in plastic containers covered with lids ventilated with wire mesh. On return to the laboratory, most of the scale insects were kept alive and observed for emergence of any parasitoids or predators; but some adult females were preserved in 70% ethanol and subsequently prepared on microscope slides in Canada balsam, using the method of Hodgson and Peronti (2012). Keys in Hodgson and Peronti (2012) were used to identify the scale insect. The slide-mounted voucher specimens have been deposited in the National Insect Museum, ICAR - National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, Karnataka, India. Parasitoids emerging from the scale colonies were preserved in 70% ethanol and were identified by the hymenopteran expert, Dr J. Poorani at the Indian Council of Agricultural Research - National Research Center for Banana (ICAR - NRCB), whereas ants were identified by one of the authors (SK). Photographs of the live coccids were taken using a Leica DFC 420 camera mounted on a Leica M205A stereozoom microscope. Slide-mounted adult females were observed through a Nikon Eclipse 80i microscope and microphotographs were captured with a Nikon DS-Vi1 camera mounted on this microscope. An Olympus U-DA drawing tube attached to an Olympus BX 51 compound microscope was used to make the taxonomic drawing, using a 0.1 mm Rotring Isograph technical drawing pen and black ink. The illustration follows the traditional format for scale insects, with features of the dorsum shown on the left side and those of the venter on the right. The habitus and enlargements around the central drawing are not drawn to scale. Fig. 1 was generated using Adobe Photoshop CS2.

## Results and discussion

The barnacle scale is reported for the first time from India, based on numerous specimens collected from a variety of host plants since 2009.

## Redescription

### *Ceroplastes cirripediformis* Comstock, 1881

*Ceroplastes cirripediformis* Comstock 1881: 333; *Ceroplastes plumbaginis* Cockerell 1893: 82; *Ceroplastes euphorbiae* Cockerell 1896: 17; *Ceroplastes mexicanus* Cockerell 1896: 20; *Ceroplastes cultus* Hempel 1900: 470; *Ceroplastes cuneatus* Hempel 1900: 471; *Ceroplastes rarus* Hempel 1900: 469; *Ceroplastes rotundus* Hempel 1900: 473; *Ceroplastes breviseta* Leonardi 1911: 264; *Ceroplastes cerripidiformis* Comstock 1881; Houser 1918: 159; *Ceroplastes cirrepediformis* Comstock 1881; Hodges 2002: 205.

**Material examined** with states given in chronological order of invasion:

**INDIA: Karnataka:** Bengaluru, Bhuvaneshwari Nagar, 12.9231° N, 77.5482° E, 15 ♀♀ on *Passiflora* sp. (Passifloraceae), 11.iii.2009, Sunil Joshi coll.; Sanjay Nagar, 13.0369° N, 77.5785° E, 10 ♀♀ on *Annona muricata* L. (Annonaceae), 1.v.2010, Sunil Joshi coll.; Anand Nagar, 13.0313° N, 77.5913° E, 10 ♀♀ on *Alternanthera* sp. (Amaranthaceae), 5.vi.2012, Sunil Joshi coll.; Hebbal, 13.0354° N, 77.5988° E, 15 ♀♀ on *Pseudoeranthemum artopurpureum* Guillaumin (Acanthaceae), 3.iv.2015, Sunil Joshi coll.; Amrutha Nagar, 13.0585° N, 77.5970° E, 5 ♀♀ on *Epipremnum aureum* (Linden & André) G.S. Bunting (Araceae), 28.iii.2015, Sunil Joshi coll.; Bhuvaneshwari Nagar, 12.9231° N, 77.5482° E, 5 ♀♀ on *Impatiens* sp. (Balsaminaceae), 11.iii.2016, Sunil Joshi coll.; Ashwath Nagar, 13.0200° N, 77.5763° E, 6 ♀♀ on *Nerium oleander* L. (Apocynaceae), 12.vii.2016, Sunil Joshi coll.; Devanahalli, 13.2437° N, 77.7172° E, 6 ♀♀ on *Crossandra infundibuliformis* L. (Acanthaceae), 12.iii.2017, Srinivasa coll.; Hebbal, 13.0294° N, 77.5850° E, 2 ♀♀ on *Impatiens* sp. (Balsaminaceae), 27.ii.2017, Harish coll.; Hebbal, Veterinary College, 13.0294° N, 77.5850° E, 7 ♀♀ on *Jacaranda mimosifolia* D. Don (Bignoniaceae), 15.iii.2017, Harish coll.; same location, 4 ♀♀ on *Tabebuia* sp. (Bignoniaceae), 15.iii.2017, Harish coll.; same location, 9 ♀♀ on *Tecoma stans* (L.) Juss. ex Kunth (Bignoniaceae), 15.iii.2017, Harish coll.; Bhuvaneshwari Nagar, 12.9231° N, 77.5482° E, 5 ♀♀ on *Pelargonium* sp. (Geraniaceae), 8.ix.2017, Sunil Joshi coll.; same location, 15 ♀♀ on *Plectranthus prostratus* Gürke (Geraniaceae), 11.ix.2017, Sunil Joshi coll.; Devanahalli, 13.2437° N, 77.7172° E, 12 ♀♀ on *Clerodendrum* sp. (Lamiaceae), 19.ix.2017, Harish coll.; same location, 20 ♀♀ on *Hibiscus rosa-sinensis* L. (Malvaceae), 19.ix.2017, Harish coll.; same location, 10 ♀♀ on *Ficus* sp. (Moraceae), 19.ix.2017, Harish coll.; Ramanagara, 12.7209° N, 77.2799° E, 20 ♀♀ on *Eugenia* sp. (Myrtaceae), 2.i.2018, Srinivasa coll.; same location, 7 ♀♀ on *Syzigium* sp. (Myrtaceae), 2.i.2018, Srinivasa coll.; Yelhanka, 13.0801° N, 77.5785° E, 4 ♀♀ on *Mangifera indica* L. (Anacardiaceae), 15.viii.2018, Sunil Joshi coll.; Bhuvaneshwari Nagar, 12.9231° N, 77.5482° E, 15 ♀♀ on *Philodendron* sp. (Araceae), 15.viii.2018, Sunil Joshi coll.; Bengaluru North, Hesaraghatta, 13.1500° N, 77.4900° E, 3 ♀♀ on *Psidium guajava* L. (Myrtaceae), 25.ix.2019, Jayanthi Mala coll.; same locality, 5 ♀♀ on *Chrysanthemum* sp. (Asteraceae), 22.vii.2021, V. Sridhar coll.; Hebbal, Veterinary college campus, 13.0294° N, 77.5850° E, 4 ♀♀ on *Pseudoeranthemum artopurpureum* Guillaumin (Acanthaceae), 11.viii. 2021, Omprakash Navik coll.; Bengaluru, Kodigehalli, Ganesh Nagar Layout, 13.0697° N, 77.5788° E, 6 ♀♀ on *Ipomoea nil* (L.) Roth. (Convolvulaceae), 27.vii.2021, Rachana coll.

**Tamil Nadu:** Tandigudi, 10.3093° N, 77.6435° E, 6 ♀♀ on *Euonymus angulatus* Wight (Celastraceae), 6.vi.2017, Sunil Joshi coll.; same location, 11 ♀♀ on *Terminalia catappa* L. (Combretaceae), 7.vi.2017, Sunil Joshi coll.; same location, 10.3093° N, 77.6435° E, 9 ♀♀ on *Cycas* sp. (Cycadaceae), 7.vi.2017, Sunil Joshi coll.; same location, 5 ♀♀ on *Codiaeum* sp. (Euphorbiaceae), 8.vi.2017, Sunil Joshi coll.; same location, 5 ♀♀ on *Euphorbia hirta* L. (Euphorbiaceae), 8.vi.2017, Sunil Joshi coll.

**Maharashtra:** Amaravati, Ganesh colony: 20.9211° N, 77.7464° E, 6 ♀♀ on *Punica granatum* L. (Punicaceae), 6.ii.2018, Sunil Joshi coll.; same location, 9 ♀♀ on *Ixora* sp. (Rubiaceae), 9.ii.2018, Sunil Joshi coll.; same location, 19 ♀♀ on *Gardenia jasminoides* J. Ellis (Rubiaceae), 9.ii.2018, Sunil Joshi coll.; Shegaon, 20.7930° N, 76.6910° E, 6 ♀♀ on *Hamelia patens* Jacq. (Rubiaceae), 15.v.2018, Sunil Joshi coll.; same location, 16 ♀♀ on *Citrus limon* L. (Rutaceae), 16.v.2018, Sunil Joshi coll.; same location, 5 ♀♀ on *Manilkara zapota* (L.) P. Royen (Sapotaceae), 17.v.2018, Sunil Joshi coll.; same location, 10 ♀♀ on *Solanum nigrum* L. (Solanaceae), 17.v.2018, Sunil Joshi coll.; Pandharpur, 17.6806° N, 75.3155° E, 12 ♀♀ on *Pyrostegia venusta* Miers (Bignoniaceae), 14.i.2021, Sachin Thite coll.

**Gujarat**: Talala: 21.0556° N, 70.5295° E, 5 ♀♀ on *Pseudoeranthemum artopurpureum* Guillaumin (Acanthaceae), 5.xii.2018, Sunil Joshi coll.

**Kerala:** Thrissur: Cherpu, 10.4380° N, 76.1476° E, 5 ♀♀ on *Citharexylum spinosum* L. (Verbenaceae), 11.iv.2019, Haseena Bhaskar coll.; Nellikunnu, 10.5161° N, 76.2361° E, 7 ♀♀ on *Malpighia emarginata* DC. (Malpighiaceae), 15.vi.2019, Haseena Bhaskar coll.; same location, 9 ♀♀ *Lannea coromandelica* (Houtt.) Merr. (Anacardiaceae), 12.x.2019, Haseena Bhaskar coll.; Thrissur, 10.5276° N, 76.2144° E, 3 ♀♀ on *Nyctanthes arbortristis* L. (Oleaceae), 10.i.2020, Sachin G. Pai coll.; Idukki, Ramakkalmedu, 9.7966° N, 77.2271° E, 15 ♀♀ on *Passiflora edulis* Sims. (Passifloraceae), 12.x.2019, Haseena Bhaskar coll.; Palakkad, Nelliampathy, 10.5348° N, 76.6928° E, 17 ♀♀ on *Passiflora edulis* Sims. (Passifloraceae), 5.ii.20, Haseena Bhaskar coll.

**Himachal Pradesh:** Palampur, 32.1109° N, 76.5363° E, 5 ♀♀ on *Duranta erecta* L. (Verbenaceae), 10.vii.2020, Ajay Sood coll.

**Uttar Pradesh:** Lucknow: 26.2647° N, 82.0727° E, 12 ♀♀ on *Cestrum diurnum* L. (Solanaceae), 2.vii.2021,

Santosh Kedar coll.; 26.2647° N, 82.0727° E, 9 ♀♀ on *Cannabis sativa* L. (Cannabaceae), 2.vii.2021, Santosh Kedar coll.

**Appearance in life** (Fig. 1): Eggs gleaming bright orange (Fig. 1K). First-instar nymph lacking wet wax, possessing only dorsal dry white wax which has a narrow horizontal slit (Fig. 1L). Second-instar nymph with developing brown nucleus (Fig. 1M). Adult female with wet wax a dirty yellowish white (Fig. 1N), with dorsal heptagonal plate, seven lateral plates, dark brown nuclei, cephalic filaments trifurcate, anterolateral and posterolateral filaments simple, posterolateral filaments and caudal filaments bifurcate, white stigmatic bands near both pairs of spiracles, anterior bands directed dorsally; body length 3.8 mm (range 2.6–4.1), width 2.4 mm (range 1.8–3.2), height 2.0 mm (range 0.8–3.2). The scale insect was collected on a wide range of host plants infesting upper and lower leaf surfaces, stems, tendrils, collar region, etc. (Fig. 1A to J).

**Appearance of slide-mounted adult female** (Fig. 2): Body circular to elliptical, 3.8–5.9 mm long, 0.5–5.0 mm wide.

*Dorsum*. Derm entirely membranous except for heavily sclerotized caudal process (Fig. 2A). Caudal process short, wider than long, 0.3–0.4 mm long, 0.4–0.6 mm wide. Derm with eight clear areas, without setae. Dorsal setae mainly capitate (Fig. 2B), each 2.9–8.8 µm long, mostly slightly longer than width of basal socket, which is 4–5 µm wide, very sparse throughout the dorsum but more numerous on marginal areas. Dorsal pores (Fig. 2C): loculate microducts of the intermediate type, those with 2 or 3 satellite loculi most abundant and widespread; those with 1 satellite loculus most frequent in submarginal region, otherwise scarce; those with 4 satellite loculi scarce; each microduct surrounded by a small clear area, forming a spotted derm pattern. Simple microducts not seen on any of the mounted specimens. Preopercular pores forming a transverse band of 9–16 pores. Anal plates (Fig. 2D) little longer than wide, each plate 100–105 µm long, combined width 95–98 µm; each plate with 3 large dorsal setae measuring 38–40 µm, 41–45 µm and 35–37 µm; and one smaller apical seta, 10–13 µm long. Anal fold (Fig. 2E) with four small anterior margin setae, each measuring 8–10 µm, and one lateral margin seta, 15–17 µm long. Anal tube 160–170 µm long, 1.6x longer than anal plate.

*Margin*. Marginal setae (Fig. 2F) each about 2 or more times longer than submarginal setae, length 23–30 µm; with 5–7 between eyespots and, on each side, 1–5 between eyespots and anterior stigmatic setae, 2 or 3 between stigmatic clefts, and about 5 or 6 on each side of abdomen; anal lobes each with 3–6 larger setae, each 40–50 µm long. Stigmatic setae (Fig. 2G) conical to lanceolate, each cleft with a group of 27–59 setae in 3 or 4 irregular rows, but group narrow and extending out of cleft along margin; most stigmatic setae each 16–22 µm long but with about 3–5 larger setae near centre of each group, each 24–31 µm long and 25–30 µm wide at base. Eyespots each 27–29 µm wide.

*Venter*. Derm entirely membranous. Pregenital disc-pores (Fig. 2H) abundant around genital opening (segment VII) and across preceding segments, distributed as follows: mesothorax with 2 or 3 pairs medially and 2–4 at the base of each coxa; metathorax, 1 or 2 pairs medially and 1–3 near base of each coxa; abdominal segment I, 0–2 pairs; II, 2–4 pairs, III, 2–5 pairs, IV, 10–15 pairs; area from segment V to genital fold with several pairs. Spiracular pores (Fig. 2I), each with five loculi, in a band of 100–200 pores between spiracle and margin; each band with few pores extending medially past peritreme. Ventral microducts normal, cruciform (Fig. 2J), seen mostly on submarginal area of head and thorax. Ventral tubular ducts (Fig. 2K) each with a long inner ductule and a small glandular end; in a group of 11–26 in cephalic region and 17–33 medially and mediolaterally on posterior abdominal segments. Ventral setae: with a pair of preopercular setae, each 50–56 µm long; submarginal setae about twice as frequent as marginal setae, each 6–9 µm long (Fig. 2L). Antennae (Fig. 2M) each with 7 segments; usually with 1 or 2 distinct pseudoarticulations in segment III; each antenna 200–320 µm long. Clypeolabral shield about 150–190 µm long and 110–150 µm wide. Spiracles (Fig. 2N): width of each anterior peritreme 50–60 µm, that of each posterior peritreme 55–65 µm. Legs (Fig. 2O) well developed, each with a distinct tibio-tarsal articulatory sclerosis; each claw without a denticle; claw digitules both broad. Dimensions of metathoracic legs (in µm): coxa 40–130; trochanter+femur 92–160; tibia 85–120; tarsus 55–77, and claw 15–25. Tarsal digitules 40–42 µm, claw digitules 30–38 µm long.

**Interspecific comparisons**: Hodgson and Peronti (2012) stated that *C. cirripediformis* is similar to *C. sinensis* Del Guercio; however, *C. sinensis* is not known to occur in India. Within the area under study, *C. cirripediformis* is most similar to *C. rusci* (Linnaeus).

In life, *C. cirripediformis* can be separated from *C. rusci* (characters of *C. rusci* given in parentheses) by its: (i) dirty yellow wet wax (dull pinkish white); (ii) heptagonal dorsal plate surrounded by seven lateral plates (octagonal domed dorsal plate surrounded by eight quadrate plates); (iii) diffused brown dorsal nucleus (very well-defined, red

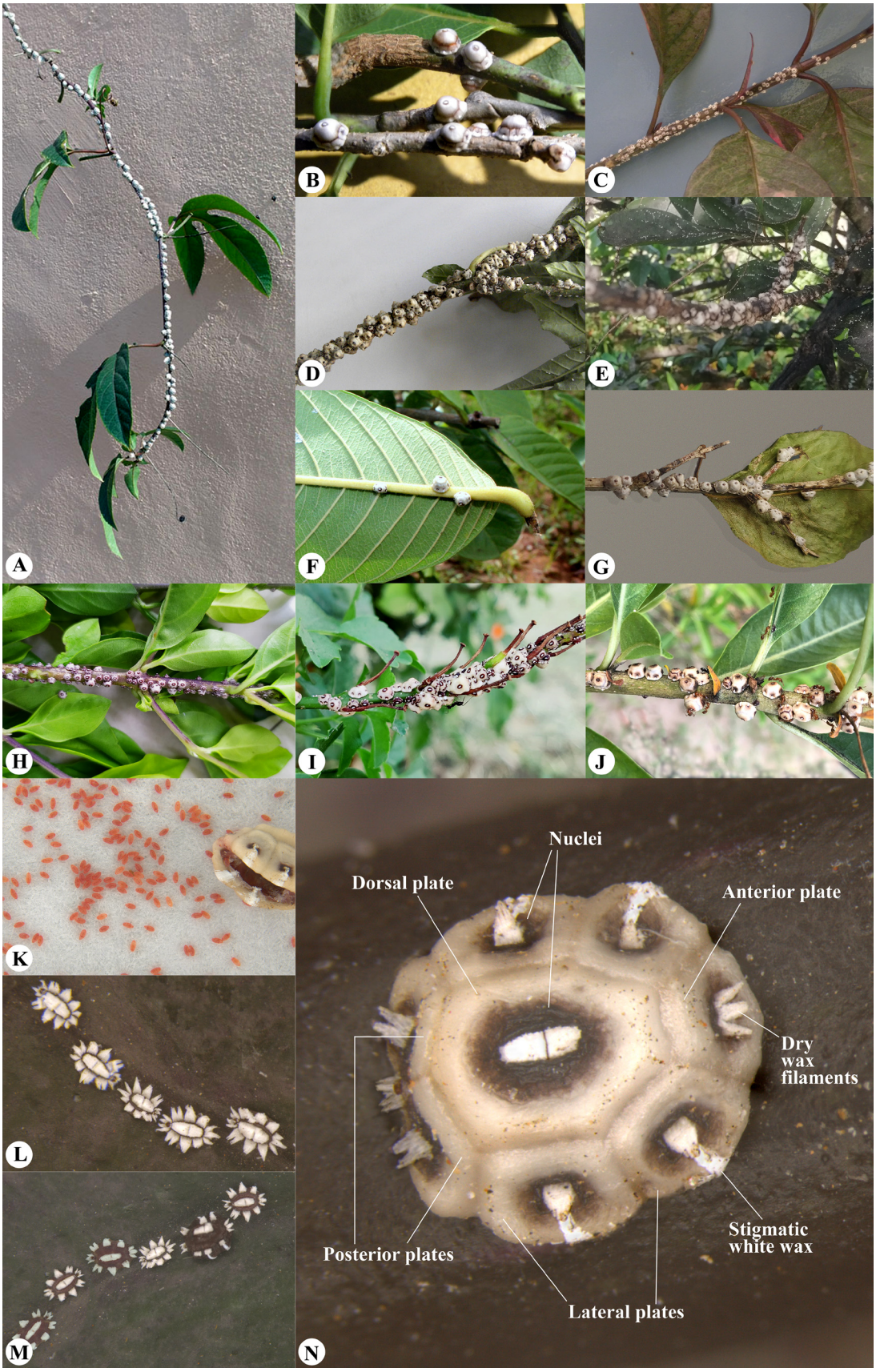


**FIGURE 1**. *Ceroplastes cirripediformis* Comstock, infestation on different host plants: A. *Passiflora* sp.; B. *Annona muricata* L.; C. *Pseuderanthemum artopurpureum* Guillaumin; D. *Crossandra infundibuliformis* L.; E. *Citharexylum spinosum* L.; F. *Psidium guajava* L.; G. *Nyctanthes arbor-tristis* L.; H. *Duranta erecta* L.; I. *Pyrostegia venusta* Miers; J. *Cestrum diurnum* L.; Life stages of *C. cirripediformis*: K. Eggs; L. First-instar nymph; M. Second-instar nymph; N. Adult female.

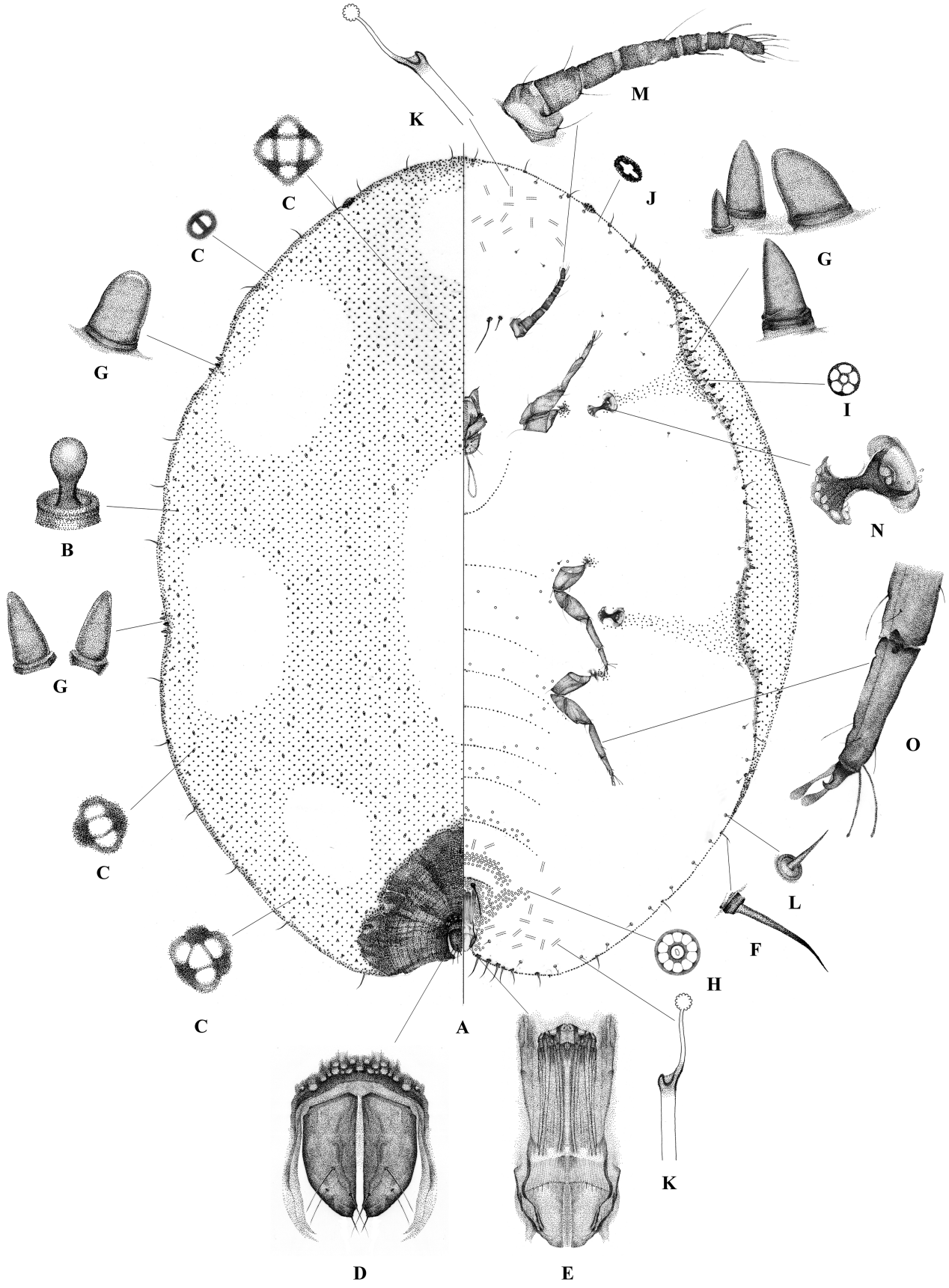


**FIGURE 2.** Taxonomic illustration of an adult female *Ceroplastes cirripediformis* Comstock. A. Body derm; B. Dorsal setae; C. Dorsal microducts; D. Anal plates; E. Anogenital fold; F. Marginal seta; G. Stigmatic setae; H. Pregenital disc–pores; I. Spiracular pore; J. Ventral microduct; K. Ventral tubular ducts; L. Submarginal setae; M. Antenna; N. Spiracle; O. Leg.

dish dorsal nucleus with a depressed margin); (iv) without darker coloration at the junction of marginal area of plates (reddish at the junction of marginal area of plates); (v) without fine radiating lines at dorsal plate margin (usually with numerous fine radiating pinkish lines).

When slide mounted, *C. cirripediformis* can be separated from *C. rusci* (characters of *C. rusci* given in parentheses) because of its (i) seven antennal segments (six segments); (ii) claw without a denticle (usually with a denticle); (iii) capitate dorsal setae (bluntly spinose dorsal setae); (iv) with 5–7 marginal setae between the eye spots (6–15 marginal setae between the eye spots).

**Distribution, host plants, damage and associated insects**: The earliest collection of *C. cirripediformis* in India was in 2009 on a home-grown passion fruit vine, but authoritative identification, after slide-mounting several specimens, was made only in 2017 and the pest was officially documented in India during 2018 (ICAR - NBAIR, 2019). The species was found to be spreading slowly to different geographical areas in India. Since 2009, this pest has been collected from 46 host plants belonging to 30 families from seven Indian states viz., Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat, Himachal Pradesh and Uttar Pradesh. *Ceroplastes cirripediformis* is widely distributed in the Nearctic, Neotropical, Palaearctic, Indo-Australian and Oriental regions, with distribution records from 32 countries on different continents (García Morales *et al*. 2016). Wang *et al*. (2020) evaluated the effects of climatic variables on distribution patterns of *C. cirripediformis*, produced a global risk map and predicted its spread to more regions, including India; however, our collection data indicate that the pest was present in India well before it was recorded in China (Li *et al*. 2018). Recently, the DNA barcode of this species was submitted to the NCBI gen bank (accession number: MW988113 from Kerala, India) and a kind of pest alert was issued in a local newspaper (Muringatheri, 2021).

Out of 46 recorded host plants, 25 were ornamentals grown in home yards, 13 fruit crops, 3 weeds, 3 medicinal and 2 avenue trees, indicating the adaptability of this scale to establish and breed in different ecosystems. It was recorded for the first time on two plant families (Oleaceae and Punicaceae) and there were 13 new host plants recorded [*Cannabis sativa* L., *Cestrum diurnum* L., *Clitoria ternatea* L., *Crossandra infundibuliformis* L., *Epipremnum aureum* (Linden & André) G.S. Bunting, *Ipomoea nil* (L.) Roth., *Ixora* sp., *Nyctanthes arbor-tristis* L., *Plectranthus prostates* Gürke, *Punica granatum* L., *Pyrostegia venusta* Miers, *Tecoma stans* (L.) Juss. Ex Kunth and *Terminalia catappa* L.]. The most serious damage in southern parts of India was found in Kerala at Idukki, Ramakkalmedu, where complete drying and death of the two-year-old passion fruit crop occurred over fifteen acres; while in northern India (in Lucknow, Uttar Pradesh), 500 $m^2$ plots of *C. diurum* and *C. sativa* suffered crop losses of 78 and 22 per cent, respectively. Four ant species viz., *Oecophylla smaragdina* Fabricius, *Camponotus compressus* (Fabricius), *Tapinoma melanocephalum* (Fabricius) and *Paratrechina* sp. (Hymenoptera: Formicidae) were found attending the scale insect. The hymenopterans viz., *Coccophagus* sp. (Aphelinidae), *Metaphycus* sp. (Encyrtidae), *Tetrastichus* sp. (Eulophidae) and *Scutellista* sp. (Pteromalidae) were found parasitizing this scale insect at different locations, however the percent parasitism was always insignificant.

**Management**: At present the main objective should be prevention of further spread of this scale insect to other host plants, through the complete destruction of infested plant parts; constant monitoring of home yard gardens, parks and fruit orchards for new infestations; recording and use of natural enemies, and use of organic chemicals to control at heavily infested sites.

**Discussion**: During the last few years, India has experienced several introductions of sternorrhynchan species, of which mealybugs viz., *Phenacoccus solenopsis* Tinsley (Hodgson *et al*. 2008), *Paracoccus marginatus* Williams and Granara de Willink (Muniappan *et al*. 2008) and *Phenacoccus manihoti* Matile Ferrero (Joshi *et al*. 2020) demonstrated rapid population growth after introduction, while other species *viz*., *Phenacoccus madeirensis* Green (Shylesha & Joshi, 2012), *Pseudococcus jackbeardsleyi* Gimpel and Miller (Mani *et al*. 2013), and the soft scale insects viz., *Trijuba oculata* (Brain) (Joshi & Rameshkumar, 2017) and *Pulvinaria urbicola* Cockerell (Joshi, 2017) are maintaining moderate population sizes on several or limited hosts for years after their first introductions. In contrast to these, there are few species of sternorrhynchans like the aphid, *Wahlgreniella nervata* (Gillette) (Joshi *et al*. 2014) and soft scales like *Kilifia acuminata* (Signoret) and *Protopulvinaria longivalvata* Green (Joshi & Rameshkumar, 2017) which were recorded only a few times after their first reports in India. On the other hand, there are other species of introduced soft scales that seem to be self-restricted, like *Hemilecanium theobromae* Newstead [which is restricted to a relatively unimportant host plant (Joshi & Kondo, 2020)] and *Platylecanium nepalense* Takagi [which is confined to a particular geographic area (Joshi & Firake, 2019)]. The invasion of *C. cirripediformis* seems to have gone through a lag phase, when it persisted in low numbers (since 2009) for about a decade, and now

its population is exploding, expanding its host and geographical ranges. Lag times in biological invasions have been studied well in some plant and animal species (Crooks & Soulé, 1999; Crooks, 2005; Kelly *et al*. 2021) that have demonstrated similar population changes after their introductions. The establishment of this scale insect warrants special attention in India as it is a potentially damaging plant pest and has a broad host range across many plant families and including many crops.

**Key to adult females of the Indian species of *Ceroplastes* Gray.** The key does not necessarily reflect phylogenetic relationships.

**Note:** Although *C. stipulaeformis* has been recorded from India, it could not be included in the key as its original description by Haworth (1812) (probably inadequate) is not available and the description in De Lotto (1971) is very scant and does not provide any precise morphological characters for separating it from other species of *Ceroplastes*. Slides of *C. ajmerensis* and *C. alami*, mounted and described by Avasthi and Shafee from the Department of Zoology, Aligarh Muslim University, Aligarh, Uttar Pradesh, India were obtained on loan for study but were found to have deteriorated; it was not possible to remount them, so their morphological character states were taken from Avasthi and Shafee (1986). All the remaining species were studied using slide-mounted specimens.

| | | |
|---|---|---|
| 1(0) | Ventral tubular ducts absent | 2 |
| - | Ventral tubular ducts present | 3 |
| 2(1) | Interantennal setae numbering 2 pairs; legs reduced; dorsal tubular ducts present; anogenital fold with 3 pairs of anterior margin setae | *C. rubens* Maskell |
| - | Interantennal setae numbering 7–10 or more pairs; legs well developed; dorsal tubular ducts absent; anogenital fold without anterior margin setae | *C. stellifer* (Westwood) |
| 3(1) | Ventral tubular ducts restricted to susbmarginal bands | 4 |
| - | Ventral tubular ducts dispersed on venter | 5 |
| 4 (3) | Tibio-tarsal sclerosis present; antenna 7 segmented; dorsum without quadrilocular pores; ventral tubular ducts each with long inner ductule | *C. ajmerensis* Avasthi & Shafee |
| - | Tibio-tarsal sclerosis absent; antenna 6 segmented; dorsum with quadrilocular pores; ventral tubular ducts each with greatly swollen, short inner ductule | *C. floridensis* Comstock |
| 5(3) | Dorsal clear areas numbering 9 or more | 6 |
| - | Dorsal clear areas numbering 8 or fewer | 7 |
| 6(5) | Dorsum with 11 clear areas; claw digitules unequal, with 1 broad and other slightly narrower; stigmatic setae restricted to cleft; multilocular disc pores absent from near procoxae; with fewer than 15 marginal setae between anterior stigmatic furrows | *C. ceriferus* (Fabricius) |
| - | Dorsum with 9 clear areas; claw digitules equally broad; stigmatic setae spreading out of cleft onto margin; multilocular disc pores present near procoxa; around 40 marginal setae present between anterior stigmatic furrows | *C. pseudoceriferus* Green |
| 7(5) | Caudal process well developed, becoming very long and broad at base at maturity; most stigmatic setae with a pronounced flange around base; claw digitules dissimilar | *C. destructor* Newstead |
| - | Caudal process variable; stigmatic setae without a pronounced flange around base; claw digitules similar | 8 |
| 8(7) | Antenna 7 segmented; claw without a denticle; dorsal setae capitate; multilocular disc pores present on derm near each coxa | *C. cirripediformis* Comstock |
| - | Antenna 6 segmented; claw with a denticle; dorsal setae not capitate; multilocular disc pores absent from thoracic segments | 9 |
| 9(8) | Dorsal setae bluntly spinose, margins almost parallel to slightly convergent with a very blunt apex, quite frequent throughout; dorsal dendritic microducts present; anterior margin of anogenital fold with 3 pairs of long setae; spiracular pores each with 5 loculi | *C. rusci* (Linnaeus) |
| - | Dorsal setae small and thick with bluntly pointed or truncate apices, sparse; dorsal dendritic microducts absent; anterior margin of anogenital fold with 4 pairs of setae; spiracular pores each with 5–7 loculi | *C. alami* Avasthi & Shafee |

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## References

Avasthi, R.K. & Shafee, S.A. (1986) Species of Ceroplastinae (Homoptera: Coccidae) from India. *Journal of the Bombay Natural History Society*, 83, 327–338.

Bartlett, B.R. (1978) Coccidae. *In:* Clausen, C.P. (Ed.), *Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review*. Agricultural Research Service, United States Department of Agriculture Washington, D.C., pp. 57–74.

Cockerell, T.D.A. (1893) Records of West Indian Coccidae, I. *Journal of the Institute of Jamaica*, 1, 373.

Cockerell, T.D.A. (1896) Notes and descriptions of the new Coccidae collected in Mexico by Prof. C.H.T. Townsend. *Bulletin, United States Department of Agriculture, Division of Entomology*, Technical Series, 4, 31–39.

Comstock, J.H. (1881) Report of the entomologist. Part II. Report on scale insects. *In: Report of the Commissioner of Agriculture, United States Department of Agriculture*, 1880/1881, pp. 276–349.

Crooks, J.A. (2005) Lag times and exotic species: The ecology and management of biological invasions in slow-motion. *Ecoscience*, 12 (3), 316–329.
https://doi.org/10.2980/i1195-6860-12-3-316.1

Crooks, J.A. & Soulé, M. (1999) Lag times in population explosions of invasive species: causes and implications. *In:* Sandlund, O.T., Schei, P.J. & Viken, A. (Eds.), *Invasive Species and Biodiversity Management*. *Population and Community Biology Series. Vol. 24*. Springer, Dordrecht, pp. 103–125.
https://doi.org/10.1007/978-94-011-4523-7_7

De Lotto, G. (1971) On some genera and species of wax scales (Homoptera: Coccidae). *Journal of Natural History*, 5, 133–153.
https://doi.org/10.1080/00222937100770091

García Morales, M., Denno, B.D., Miller, D.R., Miller, G.L., Ben-Dov, Y. & Hardy, N.B. (2016) ScaleNet: a literature-based model of scale insect biology and systematics. *Database*, 2016, bav118. Available from: http://scalenet.info (accessed 25 August 2021)
https://doi.org/10.1093/database/bav118

Gill, R.J. (1988) *The Scale Insects of California. Part 1. The Soft Scales* (*Homoptera: Coccoidea: Coccidae*). California Department of Food & Agriculture, Sacramento, California, 132 pp.

Gimpel, W.F., Miller, D.R. & Davidson, J.A. (1974) A systematic revision of the wax scales, genus *Ceroplastes*, in the United States (Homoptera; Coccoidea; Coccidae). *University of Maryland, Agricultural Experiment Station, Miscellaneous Publication*, 841, 1–85.

Haworth, A.H. (1812) XI.—Observations on the *Coccus vitis*; with remarks on some other insects of that destructive genus. *Transactions of the Entomological Society of London*, 1, 297–309.

Hempel, A. (1900) As coccidas Brasileiras. *Revista do Museu Paulista. São Paulo*, 4, 365–537.

Hodges, G. (2002) Pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green). Pest Alert. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, No. 01652. Available from: https://www.fdacs.gov/content/download/66442/file/Pest_Alert_-_Maconellicoccus_hirsutus,_Pink_hibiscus_mealybug.pdf (accessed 31 August 2021)

Hodgson, C.J., Abbas, G., Arif, M.J., Saeed, S. & Karar, H. (2008) *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. *Zootaxa*, 1913 (1), 1–35.
https://doi.org/10.11646/zootaxa.1913.1.1

Hodgson, C.J. & Peronti, A.L.B.G. (2012) A revision of the wax scale insects (Hemiptera: Sternorrhyncha: Coccoidea: Ceroplastinae) of the Afrotropical Region. *Zootaxa*, 3372 (1), 1–265.
https://doi.org/10.11646/zootaxa.3372.1.1

Houser, J.S. (1918) The Coccidae of Cuba. *Annals of the Entomological Society of America*, 11, 157–172.
https://doi.org/10.1093/aesa/11.2.157

ICAR-NBAIR (2019) Annual Report 2018–19. ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, 100 pp.

Joshi, S. (2017) First record of *Pulvinaria urbicola* Cockerell (Hemiptera: Coccidae) from India, with a key to the Indian species of *Pulvinaria* Targioni Tozzetti. *Zootaxa*, 4236 (3), 533–542.
https://doi.org/10.11646/zootaxa.4236.3.7

Joshi, S. & Firake, D.M. (2020) First record of *Platylecanium nepalense* Takagi (Hemiptera: Coccomorpha: Coccidae) from India, with redescription and a key to the species of *Platylecanium* Cockerell & Robinson. *Phytoparasitica*, 48 (1), 35–41.
https://doi.org/10.1007/s12600-019-00767-6

Joshi, S. & Kondo, T. (2020) First report of *Hemilecanium theobromae* Newstead (Hemiptera: Coccomorpha: Coccidae) from India. *African Entomology*, 28 (2), 425–432.

https://doi.org/10.4001/003.028.0425
Joshi, S. & Rameshkumar, A. (2017) Silent foray of three soft scale insects in India. *Current Science*, 112 (3), 629–635. https://doi.org/10.18520/cs/v112/i03/629-635
Joshi, S., Lokeshwari, D., Krishna Kumar, N.K., Manjunatha, H., Verghese, A. & Jalali, S.K. (2014) *Wahlgreiella nervata* (Hemiptera: Aphididae), A new pest of rose in India. *Florida Entomologist*, 97 (1), 162–167. https://doi.org/10.1653/024.097.0122
Joshi, S., Pai, S.G., Deepthy, K.B., Ballal, C.R. & Watson, G.W. (2020) The cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Coccomorpha: Pseudococcidae) arrives in India. *Zootaxa*, 4772 (1), 191–194. https://doi.org/10.11646/zootaxa.4772.1.8
Kelly, C.L., Schwarzkopf, L., Gordon, I.J. & Hirsch, B. (2021) Population growth lags in introduced species. *Ecology and Evolution*, 1, 4577–4587. https://doi.org/10.1002/ece3.7352
Kosztarab, M.P. (1996) *Scale insects of Northeastern North America. Identification, biology, and distribution.* Virginia Museum of Natural History Martinsburg, Virginia, 650 pp.
Leonardi, G. (1911) Contributo alla conoscenza delle coccinglie della República Argentina. (In Italian). *Bollettino del R. Laboratorio di Entomologia Agraria di Portici*, 5, 237–284.
Li, G., Wang, X.B. & Wu, S.A. (2018) *Ceroplastes cirripediformis* Comstock: a new invasive pest in China (Hemiptera: Coccormorpha: Coccidae). *Chinese Journal of Applied Entomology*, 55 (3), 527–532. https://doi.org/10.7679/j.issn.2095–1353.2018.066
Mani, M., Joshi, S., Kalyansundaram, M., Shivaraju, C., Krishnamoorthy, A., Asokan, R. & Rebijth, K.B. (2013) A new invasive jackbeardsley mealybug, *Pseudococcus jackbeardsleyi* (Hemiptera: Pseudococcidae) on papaya in India. *Florida Entomologist*, 96, 242–245. https://doi.org/10.1653/024.096.0135
Miller, D.R., Rung, A. & Parikh, G. (2014) Scale Insects, edition 2, a tool for the identification of potential pest scales at U.S.A. ports-of-entry (Hemiptera, Sternorrhyncha, Coccoidea). *ZooKeys*, 431, 61–78. https://doi.org/10.3897/zookeys.431.7474
Muniappan, R., Shepard, B.M., Watson, G.W., Carner, G.R., Sartiami, D., Rauf, A. & Hammig, M.D. (2008) First report of the papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), in Indonesia and India. *Journal of Agricultural and Urban Entomol*ogy, 25, 37–40. https://doi.org/10.3954/1523–5475–25.1.37
Muringatheri, M. (2021) Control method developed against invasive alien insect. Thrissur. The Hindu, 17 June 2021. Available from: https://www.thehindu.com/news/national/kerala/control-method-developed-against-invasive-alien-insect/article34841254.ece (accessed 23 August 2021)
Ouvrard, D., Kondo, T. & Gullan, P.J. (2013) Scale insects: major pests and management. *In: Encyclopedia of Pest Management.* Taylor and Francis, New York, New York, pp. 1–4.
Shylesha, A.N. & Joshi, S. (2012) Occurrence of Madeira mealybug, *Phenacoccus madeirensis* Green (Hemiptera: Pseudococcidae) on cotton in India and record of associated parasitoids. *Journal of Biological Control*, 26, 272–273.
Wang, F., Wang, D., Guo, G., Zhang, M., Lang, J. & Wei, J. (2020) Potential distributions of the invasive barnacle scale *Ceroplastes cirripediformis* (Hemiptera: Coccidae) under climate change and implications for its management. *Journal of Economic Entomology*, 114 (1), 82–89. https://doi.org/10.1093/jee/toaa245