The invasive azedarach scale *Aulacaspis crawii* (Cockerell, 1898) (Hemiptera, Diaspididae) in India

Alien invasive species pose major economic and environmental threats that affect ecosystems, human health and economies[1–3]. Of all the invaders, insects are highly successful due to their ability to escape detection, rapid reproduction and quick dispersal[4].

Diaspididae, the armoured scales, constitute the largest family within Coccoidea, the superfamily of scales and mealybugs. The family comprises 2695 named species placed in 417 genera[5]. They include many economically important pest species of forest, fruit and ornamental crops throughout the world, and are among the most common species found on imported plant products[6]. The genus *Aulacaspis* Cockerell, 1893 is represented by 151 species globally[5]. Varshney[7] has listed 20 species of *Aulacaspis* from South Asia. The invasive *Aulacaspis crawii* (Cockerell, 1898), native to Asia, was described from specimens intercepted at the San Francisco port, USA, in wood imported from China[8]. Now distributed in 16 countries in Africa, Asia, Europe and North America, *A. crawii* has been recorded on 18 species in 16 genera belonging to 13 plant families[5]. Commonly called 'azedarach scale', *A. crawii* is so far not known from India, though García Morales *et al.*[5] have erroneously mentioned its occurrence in the country and wrongly attributed the same to Giliomee[9]. However, Giliomee[9] deals with African fauna and there is no mention of *A. crawii* occurring in India. Varshney's[7] catalogue also does not mention its occurrence in India.

Melia dubia Cav. (Meliaceae), commonly called Malabar neem, is a fast-growing tree species native to tropical Asia, suitable for timber, plywood, pulpwood and fuelwood. In addition to the wood industry, it is also used in traditional medicine. Hence, *M. dubia* is gaining importance in industrial plantations and agroforestry systems[10].

Incidence of the azedarach scale was first observed by two of the present authors (S.P.S. and B.K.) in October 2021 at the Indian Institute of Science campus in Bengaluru on a single young tree of *Melia* sp. (probably *M. dubia*). The tree was part of the natural vegetation of the campus that is untended by gardeners and hence does not receive additional care in terms of watering, fertilizers or pesticides. The scales completely covered the main stem; however, the branches were free of the infestation. Insects attached to the main stem, including males and females, were collected for further studies. After a few days, the plant died, apparently due to heavy infestation of the scale. The similar infestation was observed later on in other *Melia* trees in the vicinity; however, other plant species in the same locality remained free of *A. crawii* infestation.

From January to March 2022, infestation of *A. crawii* was noticed on *M. dubia* in two localities in Kerala, viz. Alayamon Panchayath, Kollam district (8°53′42.2″N, 76°56′53.2″E) and the Main Campus of Kerala Agricultural University (KAU), Thrissur (10°33′03.69″N, 076°17′48.12″E). At Alayamon, on 8 February 2022, in a one-yr-old monoculture plantation of 420 plants of *M. dubia*, 16 were found to be seriously infested. The infested trees recovered following application of chlorpyriphos by the farmer.

In the KAU campus, infestation was observed on *M. dubia* in a plantation of five fast-growing native tree species, viz. *Acrocarpus fraxinifolius* Arn., *Ailanthus triphysus* (Dennst.) Alston, *Gmelina arborea* Roxb. ex Sm., *M. dubia* and *Neolamarckia cadamba* (Roxb.) Bosser. This is a 20-month-old plantation of 2850 trees, comprising 570 plants each of the five species. In a plot of 49 *M. dubia* trees, planted at a spacing of 1.5 × 1.5 m, 12 were infested by the scale during the last week of January 2022. Within two weeks, three of the infested trees succumbed to pest attack. However, infestation was absent in plots in which high density (1 × 1 m) and low density (2 × 2 m and 2.5 × 2.5 m) planting of *M. dubia* was adopted.

In both localities, the scales completely covered the main trunk from the base, up to a height of 12 m. The bark appeared conspicuously white even from a distance (Figure 1 *a*). The extent and nature of damage makes *A. crawii* a deadly pest of *M. dubia*, that can kill the trees within weeks.

The preserved specimens were slide-mounted in Canada balsam following Miller and Davidson[11]. Morphological terminology also follows the same authors. The species was identified based on the description of

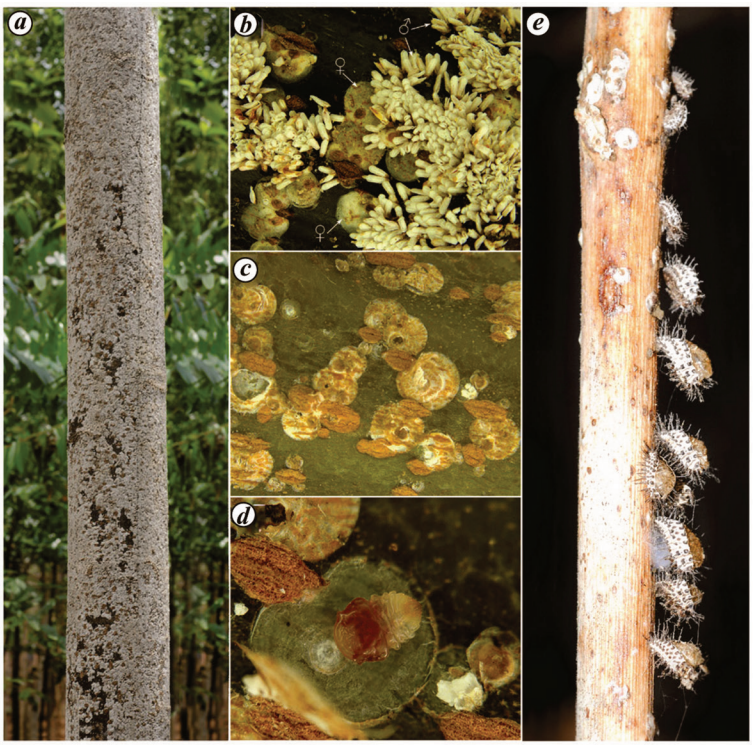

Figure 1. Field characters of *Aulacaspis crawii* (Cockerell): ***a***, Heavily infested tree trunk; ***b***, close up of females and males; ***c***, older female covers showing tree bark pattern; ***d***, mature female with scale cover overturned; ***e***, pupae of *Chilocorus circumdatus* (Gyllenhall).

Aulacaspis spp. by Takagi and Faveri[12]. Observations on the morphology of the slide-mounted female were based on 45 specimens mounted on six slides. Photographs of the live coccids were taken using a camera (Leica DFC 420) mounted on a stereozoom microscope (Leica M205A) (Figure 1 *b*–*d*). Slide-mounted adult females were observed through a microscope (Nikon Eclipse 80i) and photomicrographs were captured with a camera (Nikon DS-Vi1) mounted on the microscope (Figure 2). Figure 1 *a* and *e* were taken using a 60 mm Micronikor lens mounted on a Nikon D3000 camera body. All the plates were generated using Adobe Photoshop CS2.

Material examined, Karnataka: Bengaluru, C.V. Raman Road, Sadashiva Nagar, 13°01′11.21″N, 77°33′57.78″E, 10 ♀♀ on *Melia* sp. (Meliaceae), 06.ix.2021, Shantanu Shukla coll.; same location, 16 ♀♀ on same host, 24.xi.2021, Shantanu Shukla coll.; Kerala: Alayamon Panchayath, Kollam, 8°53′42.2″N, 76°56′53.2″E, 3 ♀♀ on *Melia dubia* (Meliaceae), 08.ii.2022, K.D. Prathapan coll.; Main campus of KAU, Thrissur, 10°33′03.69″N, 076°17′48.12″E, 16 ♀♀ on *Melia dubia* (Meliaceae), 04.iii.2022, Haseena Bhaskar coll.

Field characters: Adult female cover flat, circular or oval, dull white (Figure 1 *b*); shed skin marginal or submarginal, yellowish-brown. Old covers develop brown striations similar to tree bark pattern (Figure 1 *c*). Male cover elongate, parallel-sided, bright white, felted, with two longitudinal ridges on submarginal areas (Figure 1 *b*); shed skin marginal, yellow or brown. Males, when crowded, protrude outwards from the infested bark. Body of adult female elongate to oval, with reddish prosoma and yellow postsoma with brownish pygidium (Figure 1 *d*).

Slide-mounted specimens: Prosoma prominent, sclerotized, subquadrate, broadly round on frontal margin and broadened posteriorly; prosomatic tubercles prominent (Figure 2 *a*, marked with arrows); postsoma narrower than prosoma, membraneous except pygidium; metathorax and basal two abdominal segments subequal in width; third abdominal segment becoming narrow posteriorly; pygidium triangular. Adult female with three pairs of well-developed lobes, fourth lobe represented by sclerotized serrated areas. Apices of median lobe with strong basal zygosis; the divergent margins of lobes weakly serrated. Second and third lobes bilobed and much smaller than median lobe. Gland spine formula 1–1–1 (Figure 2 *b*). Marginal macroducts of pygidium with orifice as large as that of dorsal macroducts. I on III, two on each abdominal segments IV–VI, those on IV and V associated serrate marginal prominence (Figure 2 *c*). Prepygidial gland spines slender (Figure 2 *d*), about 10–14 and 12–18 on abdominal segments II and III respectively; marginal gland spines of pygidium small in size, 6–10 on IV, 1 or 2 on V, and 1 on VI–VIII each. Antenna each with a single seta (Figure 2 *e*). Each anterior spiracle (Figure 2 *f*) accompanied by 17–30 trilocular pores (Figure 2 *g*); posterior spiracle (Figure 2 *h*), each with 15–28 pores. Perivulvar disc pores (Figure 2 *i*): 31–34 in a median group, 53–59 in each anterolateral group, 33–42 in each posterolateral group; 117–135 in total. Perivulvar pores quinquelocular (Figure 2 *j*). Submedian dorsal macroducts occurring on abdominal segments I–VI, arranged in an infrasegmental and a segmental series on each of I–V, the infrasegmental series more or less dislocated mesally; 6–10 in infrasegmental and 6–12 in segmental series on I, 7–12 and 6–13 on II, 7–10 and 7–11 on III, 6–8 and 6–9 on IV, 5–7 and 2–5 on V, and 3–8 on VI. Submarginal dorsal macroducts occurring on abdominal segments II–V, forming only segmental rows; and 11–13 on II, 10–15 on III, 6–11 on IV, 5–10 on V. Total of submedian and submarginal macroducts on both sides: 186–308. Lateral macroducts (Figure 2 *k*) smaller than submedial and submarginal macroducts, 10–20 and 9–19 on abdominal II and III respectively, arranged along the margin of lateral lobes. A submarginal dorsal boss (Figure 2 *l*) only on abdominal segment I. Ventral side of abdominal segments II–V with flower-shaped segmental scars (Figure 2 *m*) for muscle attachment.

A total of 23 species of *Aulacaspis* are known to occur in India[5]. Of these, *Aulacaspis tubercularis* Newstead is well distributed in eight states[5] and can be easily separated from *A. crawii* by the presence of only one dorsal macroduct on abdominal segment VI (3–8 in *A. crawii*) and anterior spiracle with 7–12 trilocular pores (17–30 in *A. crawii*).

With regard to natural enemies, the predatory ladybird beetle *Chilocorus circumdatus* (Gyllenhall) (Coleoptera, Coccinellidae) was found associated with *A. crawii* in large numbers at Alayamon. Pupa of the coccinellid was observed hanging on branches of the trees (Figure 1 *e*). *Sticholotis rugicollis* Korschefsky, *Sticholotis cribellata* Sicard and *Sticholotis obscurella* Weise (all Coccinellidae), and an unidentified

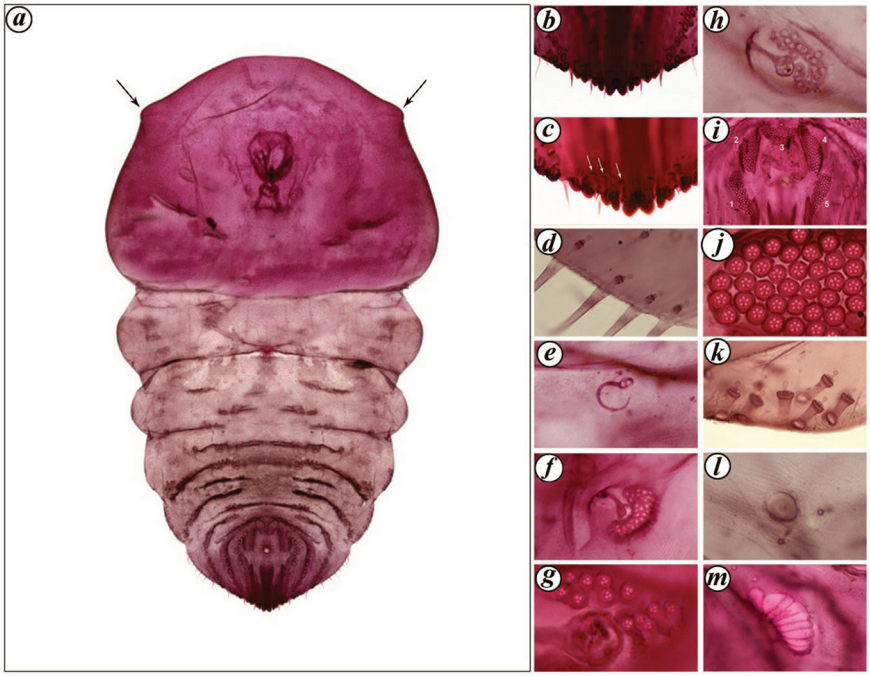

Figure 2. Diagnostic features of a slide-mounted female of *A. crawii* (Cockerell): ***a***, Female derm; ***b***, apex of pygidium showing lobes and gland spines; ***c***, dorsal macroducts associated with pygidial margin; ***d***, prepygidial spine glands; ***e***, antenna; ***f***, anterior spiracle; ***g***, close up of trilocular pores associated with spiracles; ***h***, posterior spiracle; ***i***, perivulvar pores in five groups; ***j***, close up of prevulvar quinquelocular pores; ***k***, lateral macroducts; ***l***, dorsal boss; ***m***, flower shaped segmental scars.

Cybocephalus species (Cybocephalidae) were found on *A. crawii* at the KAU campus. Studies are necessary to ascertain the role of natural enemies in keeping the pest population at low levels.

In general, characters observed in the material collected from India agree well with the description of the species by Takagi and Faveri[12]; however, spiracular pores and perivulvar pores were fewer in number. Also Takagi and Faveri[12] could observe one submarginal dorsal boss on abdominal segment I and another between segments III and IV, while in the specimens examined by us, dorsal boss was observed only on abdominal segment I.

Cockerell[13] reported *A. crawii* on twigs of *Melia azedarach* L. in Natal, South Africa. To the best of our knowledge, there are no previous reports of *A. crawii* in India. Reports of *M. dubia* as a host of the scale and its natural enemies are also lacking.

Voucher specimens of *A. crawii*, *Chilocorus circumdatus* (accession nos NIM/NBAIR/COL/CHIL/30522-1 and NIM/NBAIR/COL/CHIL/30522-2) and *Cybocephalus* spp. (accession nos NIM/NBAIR/COL/CYBO/30522-1 and NIM/NBAIR/COL/CYBO/30522-2) are deposited in ICAR-National Bureau of Agricultural Insect Resources, Bengaluru whereas specimens of *Sticholotis* spp. are deposited with J. Poorani (ICAR-NRC for Banana, Tiruchirapalli).

A. crawii is an Asian species known to attack citrus, mango, orchids and ornamental plants. It was intercepted on mango fruit in a baggage from El Salvador in 2001 and on citrus fruit and leaves of *Aglaia*, *Buxus*, *Cymbidium*, *Pelea* and *Syringa* from Asia and Hawaii[6]. Thus, it has often been intercepted at different ports of entry and hence should have been considered a potential threat since it attacks several economically important hosts.

No information on the life cycle of this scale insect is available in the literature. As the pest has become serious now, it would be desirable to study its life process to ascertain its natural mortality factors. Since 1911, several species of scale insects have unintentionally been introduced into India and many have established, attained pest status and spread far and wide. Many scale insects have been intercepted and identified from fruit and plant materials imported from Sri Lanka, Thailand, Egypt and the United Arab Emirates at different ports of entry[14]. Management of alien invasive species thus far has been initiated only after establishment and population explosion to the point where it is causing economic damage; however, the ideal approach would be taking precautionary measures that would prevent entry and establishment of alien species in the country by adopting stringent quarantine measures at all ports of entry and land crossings[6].

Field and mounted female characters illustrated and described here will help in quick identification, monitoring and spreading of awareness about the species, while information on its natural enemies would lead to the biological control of the new entrant and thus minimize the economic losses.

1. Crooks, J., *Oikos*, 2002, **97**, 153–166.
2. Pimentel, D., Zuniga, R. and Morrison, D., *Ecol. Econ.*, 2005, **52**, 273–288.
3. Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D. and Mao, M. Y., *Am. J. Prev. Med.*, 2013, **44**, 139–145.
4. Liebhold, A. M., Yamanaka, T., Roques, A., Augustin, S., Chown, S. L., Brockerhoff, E. G. and Pyšek, P., *Biol. Invas.*, 2016, **18**, 893–905.
5. García Morales, M., Denno, B. D., Miller, D. R., Miller, G. L., Ben-Dov, Y. and Hardy, N. B., ScaleNet: a literature-based model of scale insect biology and systematics, 2016; doi:10.1093/database/bav118, http://scalenet.info.
6. Evans, G. A. and Dooley, J. W., In *Potential Invasive Pests of Agricultural Crops* (ed. Peña, J.), CAB International, 2013, pp. 320–341.
7. Varshney, R. K., Occasional Paper No. 191, Zoological Survey of India, 2002, p. 147.
8. Cockerell, T. D. A., *Psyche*, 1898, **8**, 190–191.
9. Giliomee, J. H., *Ann. Univ. Stellenbosch* (*Sect. A*), 1966, **41**, 411–428.
10. Goswami, M., Bhagta, S. and Sharma, D., *Int. J. Econ. Plants*, 2020, **7**, 29–33.
11. Miller, D. R. and Davidson, J. A., *Armored Scale Insect Pests of Trees and Shrubs*. Cornell University Press, Ithaca, NY, USA, 2005, p. 442.
12. Takagi, S. and De Faveri, S., *Insecta Matsumurana (New Ser.)*, 2009, **65**, 101–129.
13. Cockerell, T. D. A., *Entomologist*, 1901, **34**, 223–227; 248–250.
14. Joshi, S., In Paper presented at XIX International Plant Protection Congress, Hyderabad, 10–14 November 2019, pp. 168–169.

ACKNOWLEDGEMENTS. We thank J. Poorani (ICAR-NRC for Banana, Tiruchirapalli, Tamil Nadu, India) for identification of Coccinellidae and J. H. Giliomee (Stellenbosch University, South Africa) for answering our questions on the reported occurrence of *A. crawii* in India. S.J. thank K. Harish for laboratory assistance. S.P.S. acknowledges funding from the Department of Biotechnology, and the Science and Engineering Research Board, Government of India.

Received 2 June 2022; revised accepted 1 July 2022

SUNIL JOSHI[1,*]
K. D. PRATHAPAN[2]
M. M. SREEJITH[3]
HASEENA BHASKAR[4]
SHANTANU P. SHUKLA[5]
BABITA KUMARI[5]
T. K. KUNHAMU[3]

[1]*ICAR-National Bureau of Agricultural Insect Resources,*
Post Bag No. 2491,
H.A. Farm Post, Bellary Road,
Bengaluru 560 024, India
[2]*Department of Agricultural Entomology,*
College of Agriculture,
Kerala Agricultural University,
Vellayani,
Thiruvananthapuram 695 522, India
[3]*Department of Silviculture and Agroforestry,*
College of Forestry,
Kerala Agricultural University,
Vellanikhara,
Thrissur 680 656, India
[4]*Department of Agricultural Entomology,*
College of Agriculture,
Kerala Agricultural University,
Vellanikhara,
Thrissur 680 656, India
[5]*Department of Molecular Reproduction, Development and Genetics,*
Indian Institute of Science,
Bengaluru 560 012, India
**For correspondence.*
e-mail: sunjoshi.pdbc@gmail.com