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 Diaispididae, 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. 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.5 The genus Aulacaspis Cockerell, 1893 is represented by 151 species globally.6 Varshney7 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.9 Commonly called ‘azedarach scale’, A. crawii is so far not known from India, though Garcia Morales et al.10 have erroneously mentioned its occurrence in the country and wrongly attributed the same to Giliomee11. However, Giliomee8 deals with African fauna and there is no mention of A. crawii occurring in India. Varshney’s 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.12

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-year-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. 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 x 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 x 1 m) and low density (2 x 2 m and 2.5 x 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 made 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 Davidson11. 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 (Gyllenhal).
Aulacaspis spp. by Takagi and Faveri. 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 stereo-zoom 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 Micronikon 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, Shantnu Shukla coll.; same location, 16 ♀♂ on same host, 24.xi.2021, Shantnu Shukla coll.; Kerala: Alayamon Panchayath, Kollam, 8°53′42.2″N, 76°56′53.2″E, 3 ♀♂ on Melia dubia (Meliaceae), 08.i.2022, K.D. Prathapan coll.; Main campus of KAU, Thirssur, 10°33′03.69″N, 76°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 postoma 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); postoma narrower than prosoma, membranous 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 submedian 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. Of these, Aulacaspis tuberculavis Newstead is well distributed in eight states 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 Weise, Sticholotis cibelata Sicard and Sticholotis obscurella Be Weise (all Coccinellidae), and an unidentified...
Coccocephalus species (Cycocephalidae) 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; however, spiracular pores and perivulvar pores were fewer in number. Also Takagi and Faveri 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.

Cockrell 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 Cycocephalus 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, Peleu and Syringa from Asia and Hawaii. Thus, it has often been intercepted at different ports of entry and hence should be 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. 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.

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.


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.I. 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 JOSHI1, 2
K. D. PRATHAPAN3
M. M. SREEJIYI
HASEENA BHASKAR4
SHANTANU P. SHUKLA5
BABITA KUMAR1
T. K. KUNHAMI3

1ICAR-National Bureau of Agricultural Insect Resources, Post Bag No. 2491, H.A. Farm Post, Bellary Road, Bengaluru 560 024, India
2Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695 522, India
3Department of Silviculture and Agroforestry, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur 680 656, India
4Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur 680 656, India
5Department of Molecular Reproduction, Development and Genetics, Indian Institute of Science, Bengaluru 560 012, India

For correspondence: e-mail: sunjoshi.pdbc@gmail.com