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Silent foray of three soft scale insects in India

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This study documents three scale insects, viz. *Kilifia acuminata* (Signoret) (Hemiptera: Coccidae), *Trijuba oculata* (Bain) (Hemiptera: Coccidae) and *Protopulvinaria longivalvata* Green (Hemiptera: Coccidae) from India as new entrants. All these insects are polyphagous and attack several economically important plant species. *K. acuminata* has been reported from important plant genera like *Artocarpus*, *Eugenia*, *Psidium*, *Syzigium*, *Passiflora*, *Coffea*, *Citrus*, *Litchi* and *Manilkara*, while *T. oculata* has been reported to infest *Annona*, *Ficus* and *Vitis*. *P. longivalvata* has been recorded on important crops, viz. *Mangifera*, *Psidium*, *Syzigium*, *Piper*, *Coffea*, *Citrus* and *Camelia*. Brief diagnostic characters in live and mounted condition are provided. Information about host range, distribution and natural enemies of these scale insects is also furnished. New plant host records for scales and new host–parasitoid association have been documented. Possibilities of these scale insects becoming serious pests and a threat to economically important plants are also discussed.

Keywords: Distribution, natural enemies, plant host, scale insects.

WORLDWIDE, exotic invasive species are responsible for environmental and economic problems. Although some exotic species are efficiently kept at bay through both biotic and abiotic processes, several lack effective natural enemies and undergo explosive population increases and geographic spread. Such species commonly transform and negatively affect the native ecosystems, threaten biotic integrity and contribute to the disappearance of endangered species[1–6].

While compiling records on invasive species, Pimentel *et al.*[7] documented more than 120,000 non-native species of plants, animals and microbes in USA, UK, Australia, South Africa, India and Brazil. In these countries, non-native species are estimated to cause damage at more than US$ 314 billion per annum. In Europe, Australia and North America, arthropod invasions are relatively well documented, whereas in other parts of the world, information regarding arthropod invasions is scarce and dispersed[8].

Scale insects are one of the most commonly transported groups of insects in plant trade. At the same time they are one of the most successful invasive groups of

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insects[9,10]. During the last decade, India has witnessed invasion of many sucking pests like aphids, viz. *Ceratovacuna lanigera* Zehntner[11], *Wahlgreniella nervata* (Gillette)[12], mealybugs, viz. *Phenacoccus solenopsis* Tisley[13], *Paracoccus marginatus* Williams and Granara de Willink[14], *Phenacoccus madeirensis* Green[15] and *Pseudococcus jackbeardsleyi* Gimpel and Miller[16], and the unusual spread of mealybugs within the country, viz. *Phenacoccus parvus* Morrison[17] and *Formicococcus polysperes* Williams[18].

Here we report the occurrence of three species of scales from India. Soft scales cause damage by sucking sap from different plant parts and like many other related sap-sucking insects, the soft scales eliminate honeydew from the anus. This is a sugary solution produced in the gut after feeding on the plant sap. A black sooty mould fungus often grows on the honeydew[19]. Sooty mould gives plants a sickly appearance and negatively affects physiological activities.

Surveys were conducted from 2012 to 2015 for collection of scale insects and their natural enemies in Bengaluru urban, Bengaluru rural, Chikkaballapur, Kolar, Ramanagara, Tumkuru, Dharwad, Mandya, Mysuru, Hassan and Chikkamagaluru districts of Karnataka, India. Plant parts infested with scale insect colonies were cut with secateurs and kept in plastic containers (16 cm height × 10 cm diameter) with lids ventilated using wire mesh. After being transported to the laboratory from the surveyed fields, the fully grown scale females were preserved in vials containing 70% ethanol for slide-making. Rest of the scale insect colonies was kept in the same containers for emergence of parasitoids. The scale females were preserved, mounted and identified using the techniques and keys developed by Hodgson and Henderson[19]. Terminologies for describing live and mounted scales have been used from the same authors[19]. Some scales were identified based on tools developed by ScaleNet, USDA. Parasitoids emerging from the scale colonies were preserved in 70% ethanol and later processed and curated according to standard protocol[20]. All the voucher specimens have been deposited at the Division of Insect Systematics, ICAR-National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bengaluru. Photographs of live coccids were taken using a Leica DFC 420 camera mounted on a Leica M205A stereozoom microscope. Mounted scale females were observed through Nikon Eclips 80i microscope and photomicrographs were captured with Nikon DS-Vi1 camera mounted on the same microscope. All plates were generated using Photoshop CS2.

We have examined scale insect material collected from 10 districts of Karnataka. We could record three invasive species of scale insects, viz. *Kilifia acuminata* (Signoret), *Protopulvinaria longivalvata* Green and *Trijuba oculata* (Brain). Following are the details of localities from where these three species were collected, their host range, distribution, diagnostic characters and natural enemies.

Kilifia acuminata (Signoret)

Material examined: Nephrolepidaceae: Ganganagar, Bengaluru, Karnataka (13.0210°N, 77.5880°E) on *Nephrolepis* sp., 03.iii.2012 (Sunil Joshi) (n = 26); Basawangudi, Bengaluru (12.9400°N, 77.5700°E), on *Nephrolepis* sp., 15.iv.2013 (Sunil Joshi) (n = 40).

Diagnostic characters — Live material (Figure 1 *a*): Adult female triangular with head narrow and posterior portion rounded. Transparent on the basal half and becoming gradually opaque towards apex. Colour pale green with border light yellow. With fluorescent yellow colouration around anal plate. The area above anal plate becomes brownish as the female ages. Body with central area reticulated. Eye spot visible in fully grown females.

Mounted material (Figure 2): Antenna six or seven segmented (Figure 2 *a*). Marginal setae conspicuously fringed (Figure 2 *b*). Stigmatic setae differentiated from other marginal setae, the middle seta longer than lateral setae (Figure 2 *c*). Claw without a denticle and claw digitules equal (Figure 2 *d*). Tibio-tarsal sclerosis present, but spur absent or broadly rounded (Figure 2 *e*). Anal plates with anterolateral margin longer than posterolateral margin and anterolateral margin less than two times the length of posterolateral margin (Figure 2 *f*). Hind two pairs of legs conspicuously larger than front legs, hind

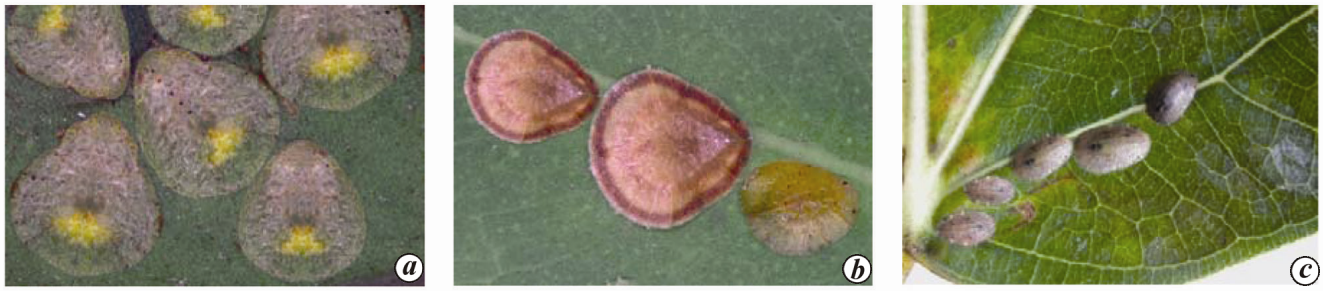

Figure 1. ***a***, *Kilifia acuminata* colony on undersurface of *Nephrolepis* leaf. ***b***, *Protopulvinaria longivalvata* on the leaf of *Syzygium* sp. ***c***, *Trijuba oculata* females infesting leaf of *Ficus* sp.

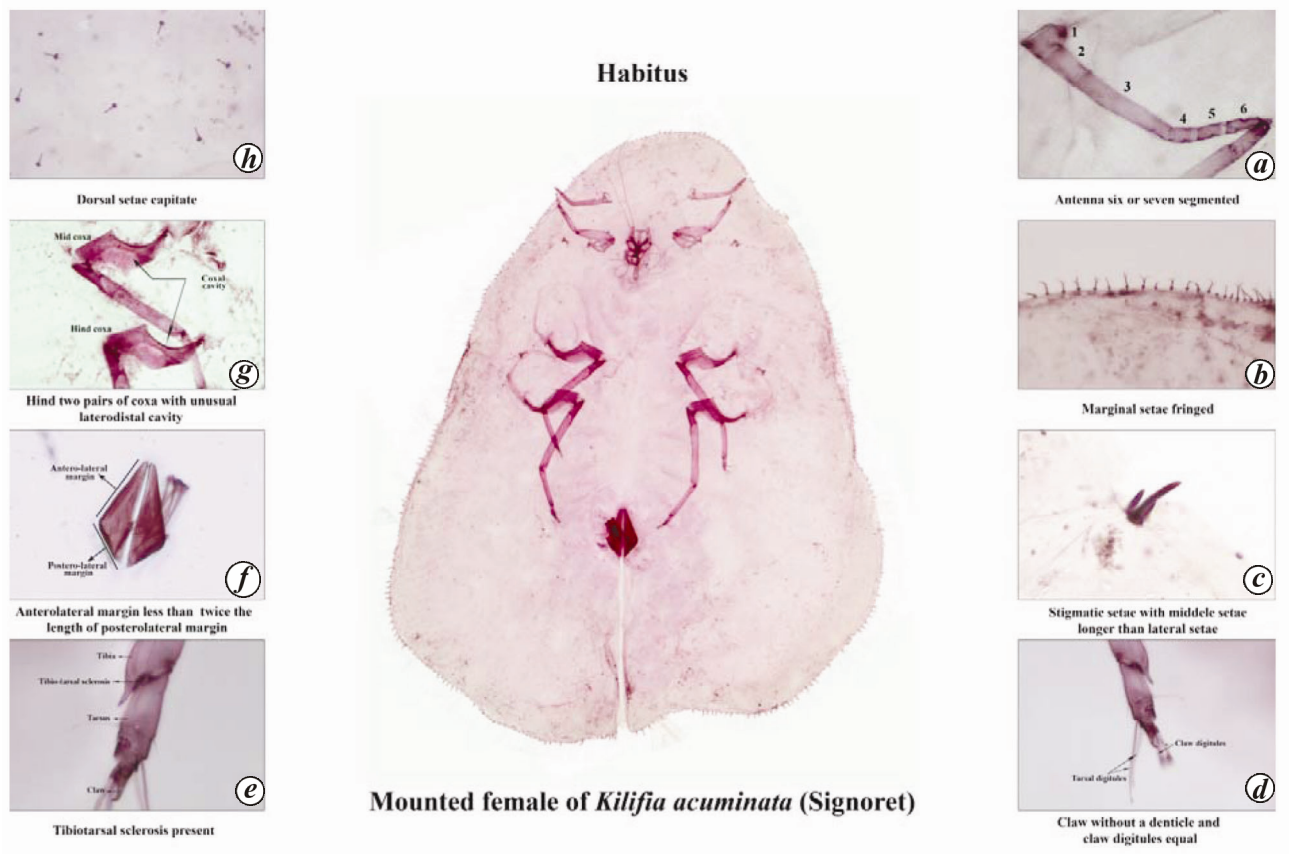

Figure 2. Diagnostic characters of mounted adult female of *K. acuminata* (Signoret).

two pairs of coxae with unusual cavity laterodistally (Figure 2 *g*). Dorsal setae capitate and anal plates situated in the middle or anterior part of abdomen (Figure 2 *h*).

Distribution and hosts: This is widely distributed scale insect which has been recorded from 35 countries, but this is the first record of this scale species from India. It has been reported from 62 species of host plants under 51 genera of 33 plant families from different countries[21]. Economically important host plants are *Mangifera indica*[22], *Eugenia* spp., *Psidium guajava*, *Syzygium cumini*, *S. jumbos*, *Passiflora* sp., *Coffeae* sp., *Citrus* spp., *Litchi sinensis*[23], *Pyrus communis*[24] and *Manilkara zapota*[25]. Occurrence of this scale on *Nephrolepis* sp. recorded in this study is new host plant record.

Natural enemies: A parasitoid *Scutellista caerulea* (Fonscolombe) (Hymenoptera: Pteromalidae) was recorded in this study. However, the per cent parasitism was very low, i.e. 6.06 (four out of 66 females collected were found parasitized). This parasitoid has been recorded earlier and used for biological control of this scale in Egypt[26].

Protopulvinaria longivalvata (Green)

Material examined: Myrtaceae: Mandya, Karnataka (12.5200°N, 76.9000°E) on *Syzygium cumini*, 11.xii. 2013 (B. Manjunath) (n = 93); Hosakote, Bengaluru, Karnataka (13.0700°N, 77.8000°E) on *Syzygium cumini*, 12.iv.2014 (B. Manjunath) (n = 115); Piperaceae: Vittal, Karnataka (12.7660°N, 75.1220°E) on *Piper nigrum*, 20.ii.2015 (Sunil Joshi) (n = 303).

Diagnostic characters — Live material (Figure 1 *b*): Adult female body pyriform with narrowest part towards the head. The scale is completely flat and holds the plant substrate tenaciously. Colour of the young females yellow with darker anal plate and reticulation all over. Fully grown females metallic golden brown in colour with dark brown border. Anal plate situated in the middle of the body is clearly visible. The anal plate and the triangular area around the anal plate lightest in colour. Light-coloured lines radiate from this area and reach up to the outer margin crossing the dark border. Eye spots dark brown to black.

Mounted material: Antenna eight-segmented (Figure 3 *a*). Marginal setae simple, but weakly fringed (Figure 3 *b*). Stigmatic setae differentiated from other marginal setae, middle seta longer than lateral setae (Figure 3 *c*). Claw without a denticle and claw digitules equal in size, and legs with presence of tibio-tarsal sclerosis (Figure 3 *d*). Fringe setae two pairs (Figure 3 *e*). Around eight submarginal tubercles around body margin (Figure 3 *f*). Pre-opercular pores restricted to area anterior of anal

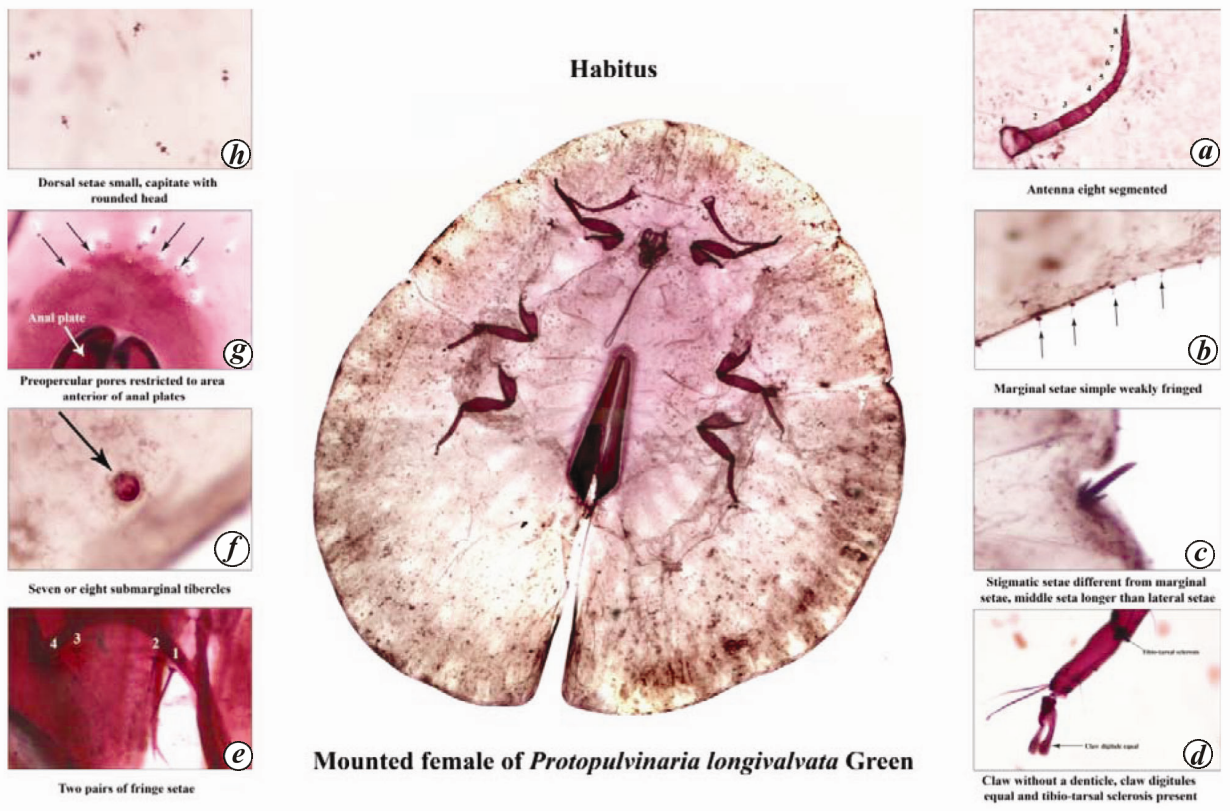

Figure 3. Diagnostic characters of mounted adult female of *P. longivalvata* Green.

plates (Figure 3 *g*). Dorsal setae small and inconspicuous and anal plates located between hind coxae, and anterolateral margin of anal plate approximately five times longer than posterolateral margin (Figure 3 *h*; see habitus).

Distribution and hosts: This species has been recorded from 14 countries, but this is the first record of this scale insect from India. It is known to occur on 22 host plants belonging to 19 genera under 13 plant families[21]. The economically important host plants of this scale are *Mangifera indica*[27], *Psidium guajava*[28], *Syzygium jumbos*[29], *Piper nigrum*[30], *Coffea* sp.[31], *Citrus* sp.[32] and *Camelia* sp.[33]. Although the scale has been recorded previously on different species of *Syzygium*, there are no earlier records on *S. cumini*.

Natural enemies: No natural enemies have so far been recorded on *P. longivalvata*; however, we could rear *Coccophagus ceroplastae* (Howard) (Hymenoptera: Aphelinidae) and *Marietta leopardina* Motschulsky (Hymenoptera: Aphelinidae) from the colony of this scale. *M. leopardina* Motschulsky is known to be hyperparasitoid of Hemiptera, including Coccidae; however, both these parasitoids have been recorded for the first time from this scale species. We could rear 60 specimens of *C. ceroplastae* and 19 specimens of *M. leopardina* from more than 511 females of the scale. The total parasitism by these parasitoids was around 15%.

Trijuba oculata (Brain)

Material examined: Annonaceae: Vasanth Nagar, Bengaluru, Karnataka (12.9900°N, 77.5900°E) on *Annona reticulata*, 6.vii. 2013 (B. Manjunath) (n = 36); Hebbal, Bengaluru, Karnataka (13.0700°N, 77.8000°E) on *Polyalthea longifolia*, 15.xi.2015 (B. Manjunath) (n = 45). Myrtaceae: Hosakote, Bengaluru (13.0700°N, 77.8000°E) on *Callistemon* sp., 23.iv.2015 (B. Manjunath) (n = 6). Fabaceae: Hebbal, Bengaluru, Karnataka (13.0700°N, 77.8000°E) on *Prosopis juliflora*, 10.iii.2015 (B. Manjunath) (n = 66). Moraceae: Mandya, Karnataka (12.5200°N, 76.9000°E) on *Ficus* sp., 15.ii.2015 (B. Manjunath) (n = 58).

Diagnostic characters — Live material (Figure 1 *c*): Adult female elongate, moderately flat, raised in the middle of the body. Buff to brown in colour. Eye spots and anal plate dark brown to almost black. Portion above anal plate yellowish. Margin brownish buff with fringe. Dorsum with three almost parallel rows of conspicuous setae.

Mounted material (Figure 4): Antenna eight-segmented (Figure 4 *a*). Spiracles small but with prominent sclerotized spiracular plate (Figure 4 *b*). Legs with tibio-tarsal articulation and small articulatory sclerosis (Figure 4 *c*). Claws without a denticle with broad equal digitules (Figure 4 *d*). Anal plates quadrate with three pairs of fringe setae (Figure 4 *e*). Marginal setae curved with flattened

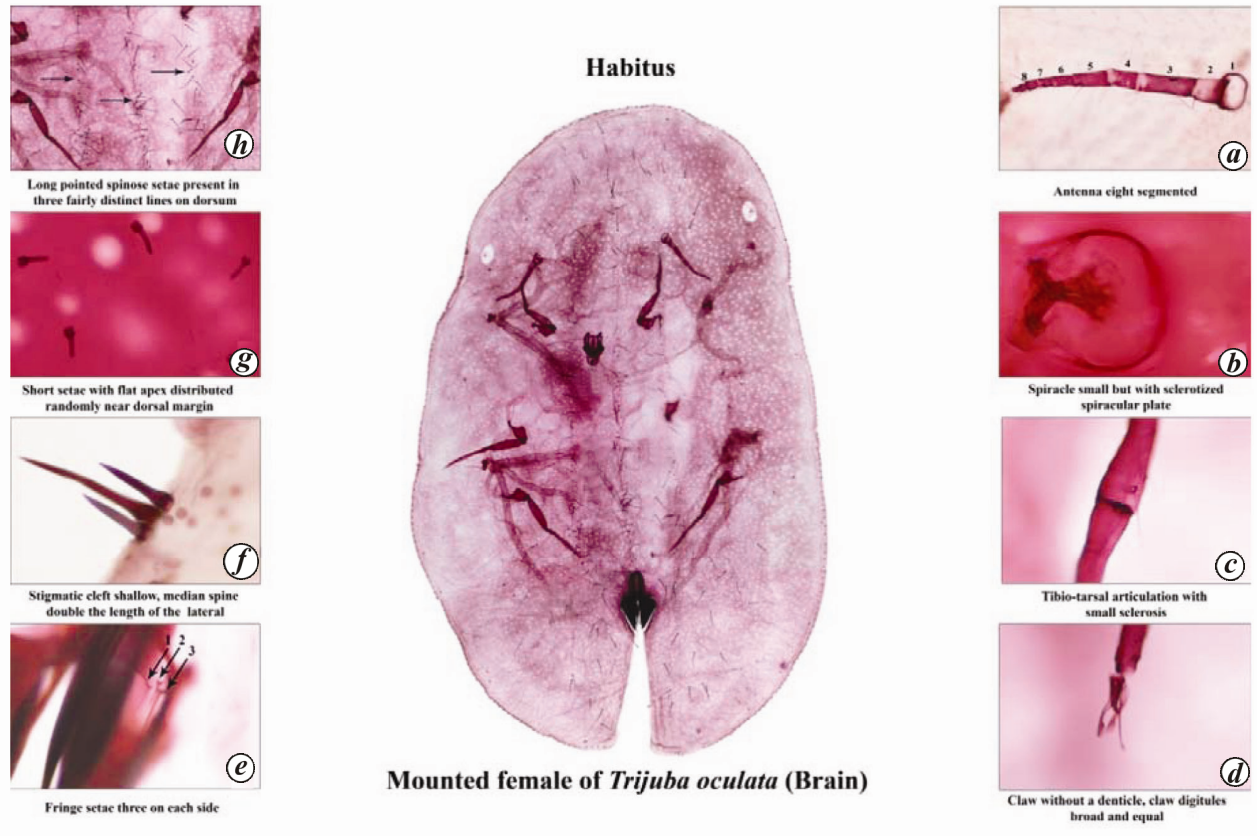

Figure 4. Diagnostic characters of mounted adult female of *T. oculata* (Brain).

apex, and stigmatic setae three in number with median setae longest and curved, lateral spines about half the length of median spine (Figure 4 *f*). Dorsal setae of two types, short mainly in sparse band submarginally and second type, very long and pointed setae (Figure 4 *g*) in three distinct lines present medially (Figure 4 *h*). Very long and pointed setae in three distinct lines present medially (Figure 4 *h*).

Distribution and hosts: This species has been recorded from six countries on ten host plants belonging to eight genera under six families[21]. The economically important host plants are *Annona reticulata*[29], *Ficus* sp.[34] and *Vitis vinifera*[35]. *Polyalthea longifolia*, *Callistemon* sp. and *Prosopis juliflora* are being recorded as new hosts for this scale species.

Natural enemies: No natural enemies could be recorded for this scale insect in the present study. No parasitoids/predators are on record throughout the world for this scale species.

Globally invasive hemipteran pests have adversely affected the production of many food, fibre and ornamental crops. India has recently witnessed accidental introduction of many hemipterans like solenopsis mealybug *Phenacoccus solenopsis* (Tinsley), papaya mealybug *Paracoccus marginatus* Williams & Granara de Willink and Jack Beardsley mealybug *Pseudococcus jackbeardsleyi* (Beardsley). These examples illustrate the seriousness of such invasions. These scale insects have not become serious pests so far, but in the event of favourable combination of intrinsic and extrinsic factors, they may cause serious damage to economically important crops.

K. acuminata (Signoret) is considered as a serious pest of mango in Egypt[36]. India ranks first among the world's mango-producing countries accounting for about 50% of mango production. During 2013–14, area under mango cultivation was 2.5 m ha with production of 18 million tonnes[37]. All South Indian states, viz. Andhra Pradesh, Karnataka, Tamil Nadu and Kerala have large area under mango cultivation, and the pest recorded in the present study can easily spread from Kerala to other states, if left unchecked. Although it was not recorded on mango in the present study, continuous monitoring for these pests should be undertaken to avoid its further spread into new areas and on new economically important hosts.

We could record *P. longivalvata*, on a pepper climber, grown in a kitchen garden, with heavy population density. Although there had been a mention about its occurrence from India[38] in minor proportion, we consider this as a new record in serious proportion as the vine was devitalized and there were several half-grown nymphs on its dried parts. The earlier publication[38] about its record from

India did not provide any information regarding deposition of the identified specimens in any museum. Hence, García *et al.*[21] may not have included India as a place of its distribution in their literature-based model of scale insects biology and systematics. Vittal, Karnataka, the place from where we collected this scale insect in large numbers, is near Kasargod, Kerala which is a major black pepper-growing area of India. This scale can easily spread to major pepper-growing areas of Kerala and can become a serious pest. At present, the parasitoids which we have recorded in the present study are perhaps keeping the scale insect in control and naturally suppressing its spread, but its accidental spread in areas with high-density pepper cropping cannot be ruled out.

T. oculata (Brain), though not recorded as a major pest in this study, shows the ability to expand its host range as indicated by new host records belonging to varied plant families. Also *Vitis vinifera*, one of its known hosts, which is grown extensively in many South Indian states, can be adversely affected by this scale.

Live and mounted female characters illustrated and described here will help generate awareness about the species and information on its natural enemies will help implement biological control efforts. This may in turn help reduce economic losses caused by the new entrants in different areas.

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Identification of generalist and specialist phenotypes of the peach-potato aphid *Myzus persicae* (Insecta : Hemiptera : Aphididae) in agroecosystem of northeast India

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Different phenotypes of the peach-potato aphid, *Myzus persicae*, with prominent differences in ecological and biological performances were identified on mustard, eggplants and potato plants in the agroecosystem of Tripura, north east India. Asexual clones of *M. persicae* on mustard plants were consistently light green in colour and their adults were heavier than the greenish yellow to light pink coloured aphids of this species that occurred on eggplants and potato plants in the same geographical area. Life history traits, like population growth rate, carrying capacity of respective plants, mean relative growth rate, intrinsic rate of increase and net reproductive rates differed between the three plant species. Differences in life history traits persisted in reciprocal host plant transfer experiments; aphid clones from mustard plants when transferred to eggplants and potato plants did not survive but those from the latter two plant species survived and colonized well on mustard plants. Results showed that *M. persicae* in the agro-ecosystem of Tripura consisted of at least two distinct phenotypes, the 'specialist' phenotypes from mustard plants and the 'generalist' phenotypes from eggplants and potato plants. These results may have significant implications for designing crop-specific measures for the management of *M. persicae*.

Keywords: Population diversity, life history traits, *Myzus persicae*, crop plants, northeast India.

AMONG insects, aphids are well known for exhibiting polymorphism, polyphenism (seasonal variations), and phenotypic plasticity in response to environmental variables including host plants[1–3]. Occurrence of asexual reproduction by parthenogenesis and viviparity in spring and summer months followed by sexual reproduction during winter have made these phytophagous insects to breed profusely with wide range of adaptations to different host plants[3]. The prevalent polyphenism and plasticity in different traits in aphids have often proved difficult to correctly identify species that are morphologically similar but show different reaction norms (differences in physiological, ecological, biological, or behavioural performances) on different host plants of agroecosystems[4].

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