Aphelinid parasitoids (Hymenoptera: Chalcidoidea) of armoured scale insects (Homoptera: Diaspididae) from India

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Abstract
The members of the family Diaspididae are among the most important pests in agriculture and considered as a promising target for the biological control programmes. These insects may attack any part of plant by sucking sap, injecting toxic saliva, due to which the trees show heavy damage resulting in collapse. However, these insects are usually parasitized by the members of the families like Aphelinidae, Encyrtidae and Signiphoridae. Among these families of parasitic hymenoptera, the members of the family Aphelinidae appear to be a dominant factor in bringing about partial to complete control of these insects. The taxonomic study of these parasitoids is essential to provide correct identification without which successful control measures cannot be achieved. Present work is a preliminary step in providing knowledge of Indian Aphelinid genera which acts as an efficient biocontrol agent against above mentioned pest species and found to be helpful in biological control programmes.

Keywords: Aphelinidae; armoured scale insects; parasitoids; India.

Introduction
The members of the family Diaspididae are commonly called as “Armoured Scale Insects” (Fig. 3) belonging to the important family in the Coccoidea because of their number, abundance and economic significance. Many species of armoured scales are among the most important pest in agriculture and considered as a promising target for the biological control programmes. They are found on all parts of the plant but are most noticeable on the fruit. Heavy infestations may cause discoloration, shoot distortion and leaf drop. The tree’s bark may split and the twigs and branches may die back and this sometimes shows heavy damage resulting in collapse. Chemical control is difficult because the insects are protected by their hard waxy coverings. They are also becoming resistant to many insecticides and pesticides. However, these armoured scales are usually parasitized by a number of chalcidoid parasitoids belonging to the families Aphelinidae, Encyrtidae and Signiphoridae. Among these families of parasitic Hymenoptera, the members of the family Aphelinidae appears to be a dominant factor in bringing about partial to complete control of armoured scale insects (Rosen and DeBach, 1979; Viggiani, 1990). In spite of the fact that large number of armoured scale Insects are responsible for damage of fruit trees resulting in loss of fruit production, so far there is no comprehensive work dealing with the armoured scale parasitoid of insects from India, however, several publications dealing with the taxonomy of Indian Aphelinidae, parasitoids reared from armoured scale hosts were also described. The following publications are of use in identifying the parasitoids: Rosen and DeBach (1979); Agrawal (1984); Hayat (1974, 1983, 1985, 1986, 1998); Compere (1955).

In present work, a generic key for the identification of the Aphelinid parasitoids of the armoured scale insects is given along with the list of these parasitoids, their total number of species in world and India and species of armoured scale insects (hosts) with their distribution in India.

Family Aphelinidae
The Chalcidoid family Aphelinidae contains 32 genera in total among which 21 genera occur in India, of these the species of the genera known to be exclusively parasitic on armoured scale insects are *Aphytis* Howard, *Coccobius* Ratzeburg, *Coccophagoides* Girault, *Encarsia* Foerster, *Marlattia* Howard, *Pteroptrix* Westwood, and *Proaphelinoides* Girault, and of these the genera *Barylis* and *Prophyscus* are not represented from India (Hayat, 1985, 1989).

The genus *Encarsia* Foerster with over 200 described species in the world contains about 20% species that are considered parasitoids of armoured scale insects.

Diagnosis of Aphelinids
Female: Small to medium sized chalcids not exceeding 1.5 mm in length, antennae 3-9 segmented, excluding the radicle and anelli
Brief notes on the Indian genera of Aphelinid parasitoids of armoured scale insects

1. Genus Aphytis Howard [Key couplet: 4] (Figs. 4-6)
Aphytis Howard, 1900: 168. Type species Aphytis chilensis Howard, by monotypy.

Diagnosis
Female
Colour of body, antennae, wings and legs variable. Antenna with 6 segments, some with 5 or 4 segments. Pronotum medially membranous, thus made up of two plates, the setae at each postero lateral corner longer than other setae along collar; mid lobe with reduced number of setae, mainly 10-12, each axilla with 1 and scutellum with 4 setae; axillae very slightly projecting forwards; mesothoracic dorsum with a median pale line or shallow groove; metanotum with an antero- median tubercle; propodeum always longer than metanotum, with a fine open ’S’-shaped ridge mesad of each spiracle and medially always variously reticulate; mesosternum long and broad. Fore wing variable, but with venation long, reaching clearly beyond half- length of wing; Legs normal, not robust; tarsal 5-segmented. Petiole transverse, usually reticulate. Gaster with 7 terga.

Species and Distribution
World species 74; India, 7 species.

2. Genus Coccobius Ratzeburg [Key couplet: 5] (Figs. 7-9)

Diagnosis
Female
Antenna with 7 segments, with an anellus. Pronotum entire, narrow in dorsal view of thorax; mid lobe of mesoscutum large, with numerous setae of which the posterior pair long; side lobes small, shaped like a trepezium, each with 2 setae; axillae small, scutellum large, posterior margin broadly rounded, usually with 4-6 setae, rarely more than 6; metanotum with a median longitudinal groove; propodeum not or not much longer than metanotum. Fore wing without a lineacalva and with a characteristically shaped stigmal vein, Tarsi 5-segmented; mid tibial spur large; mid basitarsus with peg-like setae. Gaster at least as long as thorax, rarely shorter; hoppygium not extending to apex of gaster; ovipositor variable.

Species and Distribution
World species 74; India, 7 species.

3. Genus Coccophagoides Girault [Key couplet: 6] (Figs. 10 & 11)
Coccophagoides Girault, 1915: 58. Type species Coccophagus abnormicornis Girault, by original designation.

Diagnosis
Female
Antenna with 8 segments, and usually with an anellus. Thorax depressed; pronotum medially membranous; axillae strongly produced forwards; scutellum distinctly shorter than mid lobe, each axilla and scutellum with 12-22, 2-3, 1-2, and 4-6 setae; propodeum with posterior margin medially triangularly produced. Fore wing
with marginal vein distinctly shorter than costal cell. Tarsai 5-segmented; tarsal segments generally shorter. Gaster about as long as head plus thorax; TVII band-like, latero-ventrally continuous with or connected to, outer plates of ovipositor, thus gaster with 8 terga; ovipositor at most slightly exserted; hypopygium either prominent reaching to apex or beyond of gaster, or only to about the level of cereal plates.

**Species and Distribution**
World species, 16; India, 2 species.

4. **Genus Encarsia Foerster** [Key couplet: 6] (Figs. 12-14)
Encarsia Foerster, 1878 65 Type species Encarsia tricolor Foerster, by monotypy Aspidiotiphagus Howard, 1894a 229 Type species Coccophagus citrinus Craw, by original designation Synonymy by Viggiani & Mazzone, 1979 44
Prospalta Howard, 1894b 6 Type species Coccophagus auratus Howard, designated by the ICZN, Opinion 845 Preoccupied by Prospalta Walker, 1857, in Lepidoptera Prospalta Ashmead, 1904b 126 Replacement name for Prospalta Howard, or not Walker Synonymy by Viggiani & Mazzone, 1979 44

Mimatomu Cockerell, 1911 464 Type species Mimatomu spleltatus Cockerell, by monotypy As synonym of Prospalta by Girault, 1917a 114

Doloresia Mercet, 1912b 294 Type species Prospalta flicornas Mercet, by original designation Synonymy by Mercet, 1930a 191

Prospaloides Brethes, 1914 12 Type species Prospaloides howardi Brethes, by original designation Synonymy with Aspidiotiphagus through synonymy of the type species, by Brethes, 1916 429

Paraspidotiphagus Alam, 1956 359 Type species Aspidiotiphagus flavus Compere, by original designation As subgenus of Aspidiotiphagus

Aleurodiphilus DeBach & Rose, 1981 659 Type species Aleurodiphilus amencanus DeBach & Rose, by original designation Synonymy by Hayat, 1983: 85

**Diagnosis**

**Female**
Antenna with 8 segments, scape cylindrical or slightly flattened, but never expanded beneath; relative dimensions variable. Mandibles bidentate, teeth either sharp or blunt, or weakly developed. Thoracic dorsum only a little convex, but usually on the flatter side; pronotum medially membranous, with usually 6-12 setae along collar, a seta at each postero-lateral angle conspicuously longer; mid lobe with 2-18 setae; scutellum distinctly broader than long, more or less biconvex lens shaped, with 4 setae, and a pair of pits; propodeum narrow in middle, not much longer than metanotum. Forewing shape and length of marginal fringe variable; costal cell at most as long as marginal vein, and usually with a line of minute setae on venral surface; submarginal vein with 2 setae, rarely 1 or more than 2; there is always present a strong seta at junction of submarginal vein and parastigma oron parastigma; the number of setae on (anterior margin of) marginal vein vary; postmarginal vein absent, rarely indicated and then very short and like a spur; discal setae variable, disc very sparsely to very densely setose; Hind wings narrow, with sparsely setose disc and with a row of setae extending from apex of veins to apex of wing. Legs normal; tarsai 5-segmented or sometimes midtarsai 4-segmented. Petoile transverse. Gaster with 7 terga; hypopygium never extending to apex of gaster.

**Species and Distribution**
World species, 222; India, 52 species.

5. **Genus Marlattiella Howard** [Key couplet: 2] (Figs. 15 &16)
Marlattiella Howard, 1907: 73. Type species Marlattiella prima Howard, by original designation.

**Diagnosis**

**Female**
Antenna 4-segmented; funicle segment small, quadrate or broader than long; clava long, slightly curved. Eyes small, occupying much less than half of head; malar space longer; frontovertex narrower than eye. Pronotum medially membranous; mid lobe, each side lobe and scutellum with 6, 2 and 4 setae; axilla without setae; mid lobe and scutellum with a mid-lateralinal fine line; propodeum slightly longer than metanotum, with a triangular projection in middle of posterior margin. Fore wing as in Aphytis; costal cell distinctly shorter than marginal vein and with 2 setae; linea calva distinct, proximally bordered by several lines of setae; submarginal vein with one seta; stigma vein short, but with a distinct neck, stigma with 4 sensilla. Tarsai 5-segmented. Gaster as in Aphytis; hypopygium not extending to apex of gaster.

**Species and Distribution**
World species, 2; India, 1 species.

6. **Genus Pteroptrix Westwood** [Key couplet: 1] (Figs. 17 &18)

Pteroptrix Westwood, 1833b: 344. Type species *Pteroptrix dimidiatum* Westwood, by monotypy.

*Pterothrix* Nees, 1834: 409. Invalid emendation

[Greatis Foerster, 1856: 145. Replacement name for *Pterothrix* Nees, considered preoccupied by *Pterothrix* Candolle, in plants)


Artas Howard, 1907: 85. Type species *Artas koebelei* Howard, by original designation. Synonymy by Hayat, 1983: 94.


Oa Girault, 1929b: [4]. Type species *Archenomus biguttatus* Girault, by original designation. Implied synonym of *Pteroptrix* by Viggiani, in Viggiani&Garonna, 1993: 58.


Diagnosis

Female

Extremely close to Encarsia Foerster, and especially, but differing from that genus in having all tarsi 4-segmented, antenna 7 or 8 segmented and the flagellum usually elongate, spindle-shaped.

Species and Distribution

World species, 62; Oriental, 30; India, 5 species.

7. Genus Proaphelinoides Girault

[Key couplet: 4] (Figs. 19 & 20)

Proaphelinoides Girault, 1917c: [4]. Type species *Proaphelinoides elongatiformis* Girault, by original designation.


Diagnosis

Female

Antenna 6 segmented, Mandible bidentate. Pronotum long, medially divided by a suture; mid lobe and scutellum with a fine mid-longitudinal line/groove; scutellum with a notch in posterior margin; setae on thoracic dorsum long and brown to dark brown; mid lobe, each side lobe, each axilla and scutellum with 12-16, 2, 1 and 4 setae; propodeum medially as long as metanotum and with a fine; posterior margin of propodeum with very fine crenulae. Fore wing broad, with or without a bunch of dark setae behind proximal half of marginal vein; linea calva distinct or not clearly defined, proximally bordered by 1-4 lines of setae; submarginal vein with 2 setae, the distal seta very long; marginal vein distinctly longer than costal cell and with long setae; stigma with 4 sensilla. Hind wing broad, with sparsely to moderately densely setose disc. Legs long and slender; tarsi 5-segmented. Gaster at least as long as head plus thorax; ovipositor long, slightly exserted at apex.

Species and Distribution

World species, 4; India, 2 species.

Key to Indian Aphelinid Genera, Parasitoid of Armoured Scale Insects

1. Tarsi 4 segmented, antenna 7 segmented (Fig. 17) .......................................................... *Pteroptrix* Westwood
   - Tarsi 5 segmented (Fig. 16) ........................................................................................................... 2

2. Antenna 4 segmented (Fig. 15) ................................................................................................. *Mariatiella* Howard
   - Antenna with more than 4 segments ........................................................................................... 3

3. Antenna 6 segmented (Fig. 19), propodeum longer than metanotum ........................................ 4
   - Antenna at least 7 segmented, propodeum no longer than metanotum ..................................... 5

4. Body elongated and flattened; fore wing with a branch of dark setae below marginal vein (Fig. 20)........ Proaphelinoides Girault
   - Body neither elongated nor flattened, forewing normal ..................................................... Aphytis Howard

5. Antenna 7 segmented (Fig. 7); axillae short, not protruding................................................................. Coccobius Ratzeberg
   - Antennae 8 segmented; axillae protruding ...................................................................................... Coccophagoides Girault

6. Antennae spindle shaped; forewing with marginal vein shorter than sub-marginal vein, the latter with 3 setae (Fig. 10 & 11)........... Encarsia Foerster
   - Antenna usually not spindle shaped, forewing with marginal vein longer than submarginal, the latter with 2 setae (Fig. 12 & 13)........................................................................... Encarsia Foerster

List of Aphelinid parasitoids, including total number of species (world and Indian), armoured scale insects/Diaspidids host(s) and distribution.

<table>
<thead>
<tr>
<th>Parasitoid Genera</th>
<th>Total Number of Species</th>
<th>Diaspidid Host(s)</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>World</td>
<td>India (excluding those species with unknown hosts)</td>
<td></td>
</tr>
<tr>
<td>Aphytis Howard</td>
<td>130</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Aphytis bangalorensis Rosen &amp; DeBach</td>
<td>Pseudaulacaspis barberi (Green) on Mango</td>
<td>Karnataka</td>
<td></td>
</tr>
<tr>
<td>Aphytis fiorinae (Rosen &amp; Rose)</td>
<td>Fiorinia theae (Green) on tea</td>
<td>Assam</td>
<td></td>
</tr>
<tr>
<td>Aphytis lepheidosaphes (Compere)</td>
<td>Cornuaspis beckii (Newman)</td>
<td>India without specific region</td>
<td></td>
</tr>
<tr>
<td>Aphytis lingnanensis Compere</td>
<td>Aonidiella aurantii (Maskell)</td>
<td>Near New Delhi, Assam, Uttar Pradesh, Haryana, New Delhi</td>
<td></td>
</tr>
<tr>
<td>Aphytis melinus DeBach</td>
<td>Aonidiella aurantii (Maskell) on rose indet.diaspidid on Citrus species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphytis vandenboschi DeBach &amp; Rosen</td>
<td>Quadriaspidiotus perniciosus</td>
<td>Himachal Pradesh</td>
<td></td>
</tr>
<tr>
<td>Aphytis coheni DeBach</td>
<td>Aonidiella orientalis</td>
<td>Khunti near Bihar</td>
<td></td>
</tr>
<tr>
<td>Aphytis manii Hayat</td>
<td>Hemiberlesa lataniae</td>
<td>Karnataka</td>
<td></td>
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<tr>
<td>Aphytis</td>
<td>Paralatoria oleae</td>
<td>India</td>
<td></td>
</tr>
<tr>
<td>Paramaculicornis (DeBach&amp; Rosen)</td>
<td>Aonidiella orientalis (Newstead) on rose</td>
<td>Khunti near Bihar</td>
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<tr>
<td>Aphytis peculiaris (Girault)</td>
<td>Parlatoria ziziphus (Lucas)</td>
<td>India</td>
<td></td>
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<tr>
<td>Aphytis proclia (Walker)</td>
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</table>

<table>
<thead>
<tr>
<th>Aphytis philippinensis DeBach&amp; Rosen</th>
<th>Aonidiella aurantii (Maskell)</th>
<th>Assam, Karnataka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphytis sankarani Rosen &amp;DeBach</td>
<td>Pseudaulacaspis cockerelli (Cooley) on betel nut, banana and coconut</td>
<td>Karnataka</td>
</tr>
<tr>
<td>Aphytis theae (Cameron)</td>
<td>Fiorinia theae (Green) on tea Pseudoaonidia duplex (Cockerell) on tea</td>
<td>Assam, Himachal Pradesh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coccobius Ratzeberg</th>
<th>26</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coccobius aligarhensis (Hayat)</td>
<td>Aonidiella orientalis (Newstead) on Ficus sp.</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>Coccobius eticulates (Compere &amp;Annecke)</td>
<td>Aonidiella orientalis (Newstead) on Dalbergia sisso</td>
<td>Andhara Pradesh, Uttar Pradesh, Karnataka, Maharashtra, Bihar (Khunti), Kerala</td>
</tr>
<tr>
<td>Coccobius comperei (Hayat)</td>
<td>on Indet.Diaspidids</td>
<td>Karnataka, Kerala</td>
</tr>
<tr>
<td>Coccobius fulvus (Compere &amp;Annecke)</td>
<td>Pinaspis strachani (Cooley) on Citrus sp.; Aonidiella orientalis (Newstead) on Dalbergia sisso</td>
<td>Karnataka, Uttar Pradesh</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Coccophagoides Girault</th>
<th>16</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coccophagoides utilis Doutt</td>
<td>Parlatoria oleae (Lucas) on peach</td>
<td>Bihar</td>
</tr>
<tr>
<td>Coccophagoides orientalis Agarwal</td>
<td>Aonidiella orientalis (Newstead) on neem, ziziphus, jamun etc.</td>
<td>Bihar, Rajasthan, Uttar Pradesh</td>
</tr>
</tbody>
</table>
**Encarsia Foerster**  
Encarsia citrina (Craw)  
Encarsia perniciosi (Tower)  
Encarsia perniciosi (Comstock) on apple  
Karnataka, Himachal Pradesh, Jammu & Kashmir

Encarsia elongate (Dozier)  
Encarsia sankarani Hayat  
Encarsia aurantii (Howard)  
Encarsia bifasciafacies Hayat  
Fiorinia theae(Green) on tea  
Fiorinia theae(Green) on tea  
Aonidiella orientalis  
Aonidiella orientalis on Ficus sp.  
Assam  
Assam  
Karnataka, Andhra Pradesh  
Bihar, Delhi, Uttar Pradesh

**Marlattiella Haward**  
Marlattiella maculata (Hayat)  
Aonidiella orientalis (Newstead) on Ficus sp.  
Uttar Pradesh

**Proaphelinoidis Girault**  
Proaphelinoidis maculata (Hayat)  
(Armoured scale of the tribe odonaspidini)  
Assam, Karnataka

**Pteroptrix Westwood**  
Pteroptrix chinensis (Westwood)  
Pteroptrix koebelei (Haward)  
Pteroptrix machiaveli (Girault)  
Pteroptrix longiclavata (Shafee et al)  
Quadriaspidiotus perniciosus (Comstock)  
Anlacaspis tubercularis  
Chionaspis ramakrishnai  
Aonidiella orientalis (Newstead)  
Jammu & Kashmir  
Karnataka  
Karnataka  
Uttar Pradesh

**Discussion**

The Aphelinid parasitoids had been chosen by the author as they are important in controlling the pest of agriculture especially the armoured scale insects and act as ecofriendly biocontrol agents to the environment. The taxonomic studies of these parasitoids both at generic and specific levels is important before their recommendation in any biological control program, without which an effective control measures cannot be achieved as...
misidentification leads to the failure of any biocontrol strategy.

The present work providing brief study of these parasitoids which can be identified using key to genera as well as distribution of these parasitoids and their specific hosts (armoured scale insects). The present work is helpful in providing knowledge of Indian Aphelinid genera mainly associated with armoured scale species. This work also provides important information about the distribution of aphelinid parasitoids, which is helpful in any conservation programmes of these parasitoids.

Acknowledgement
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References

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Figures

Figs. 1 & 2. Explanation of terms (Aphelinidae): 1, Antenna; 2, Forewing.

Fig. 3. Armoured Scale Insect (*Aonidiella orientalis*).
Figs. 4-6. *Aphytis* Howard: 4, Antenna; 5, Forewing, basal part; 6, Body, dorsal.

Figs. 7-9. *Coccobius* Ratzeburg: 7, Antenna; 8, Forewing, basal part; 9, Body, dorsal.

Figs. 10 & 11. *Coccophagoides* Girault: 10, Antenna; 11, Forewing, basal part.
