

BIODIVERSITY OF PREDATORS AND PARASITOIDS OF CALAPHIDINE APHIDS (HEMIPTERA: APHIDIDAE) AND THEIR HOST PLANT ASSOCIATIONS IN INDIA

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ABSTRACT

The present article lists the predators and parasitoids of the calaphidine aphids (Calaphidinae: Aphididae: Hemiptera) infesting different food plants and their distribution in various states and union territories of India. These predators belong to four orders of the class Insecta: Coleoptera (Coccinellidae), Diptera (Syrphidae), Hemiptera (Anthocoridae, Geocoridae) and Neuroptera (Chrysopidae, Coniopterygidae, Hemerobiidae). A total of 48 species of predators from various taxa were recorded to feed 17 species of the calaphidine aphids on 13 food plant species across 16 states/union territories of India. The highest number of predators belonged to the families Coccinellidae (32 species) and Syrphidae (5 species). Most of the tritrophic associations (triplets, predators-preys-host plants) of these predators were reported in Manipur (36 triplets), Jammu & Kashmir (20 triplets), Uttarakhand (13 triplets) and other states/union territories with fewer than 10 triplets. All the parasitoids of calaphidine aphids belong to a single subfamily Aphelininae (Aphelinidae: Hymenoptera) and Aphidiinae (Braconidae: Hymenoptera) in India. A total of 15 species of parasitoids were observed parasitising calaphidine aphids infesting on 11 host plants in 7 states/union territory of India. Most of the tritrophic associations (triplets, parasitoids-hosts-host plants) of these parasitoids were reported from Jammu & Kashmir (20 triplets), followed by Meghalaya (5 triplets), Uttarakhand (3 triplets), Himachal Pradesh and West Bengal (each of 2 triplets), Manipur and Uttar Pradesh (single triplet).

Keywords: *Aphidiinae, biocontrol, Braconidae, Chrysopidae, Coccinellidae, parasitoids, calaphidine aphids, predators, Syrphidae.*

INTRODUCTION

The aphids exclusively belong to the family Aphididae Latreille, 1802 (Aphidoidea: Hemiptera: Insecta) which comprises 24 subfamilies (Favret, 2024). The Calaphidinae Oestlund, 1919 the second largest subfamily in the Aphididae. Earlier, it was treated as a tribe under the subfamily Drepanosiphinae Herrich-Schaeffer, 1857 (Singh and Singh, 2017). The Calaphidinae, consists of 8 tribes, 81 genera and 434 species (Favret, 2024). Calaphidine aphids are monoecious, holocyclic (sexual generation alternates with parthenogenetic reproduction) and oligophagous. All viviparous morphs of most of the calaphidines are alate (winged). The sexual females are usually apterous while males are mostly alate (Singh and Ghosh, 2012). In India, 50 species are recorded under 24 genera associated with 70 plant species in 30 families, mostly trees of Betulaceae (birches), Fagaceae (beeches), Ulmaceae (elms), Anacardiaceae (cashews), and Juglandaceae (walnuts) and herbaceous plants like Fabaceae, Poaceae and Rosaceae (Singh and Singh, 2019; Singh *et al.*, 2023). Several species of aphids of this subfamily are economically important pests, causing injury and transmitting viral diseases to cultivated plants such as leguminous crops, fruit, and

landscape trees. Most of the host plants of these aphids are distributed in the western to eastern Himalayas region.

Aphid predators and parasitoids play an important role in the natural/biological control of aphids (Singh, 2001). Records of natural enemies of these aphids begin with Ghorpade (1973) who recorded a hover fly, *Allograpta javana* (Wiedemann, 1824), as a predator of *Therioaphis trifolii* (Monell, 1882) on alfalfa (*Medicago stiva* L.) from Karnataka. After a year, Pal (1974) recorded a geocorid predatory bug, *Geocoris jucundus* (Fieber, 1861) feeding the same species of aphid on alfalfa from Rajasthan. Similarly, Starý and Ghosh (1975, 1978) were the first to record parasitoids of these aphids from Meghalaya. Thereafter, a considerable number of predators and parasitoids were recorded from several states/union territories of India on the calaphidine aphids on several host plants of economic importance. However, these informations are sporadic records of species, isolated studies in the life cycles of individual species, and discrete information on the biology and ecology of a few species. Several records of natural enemies, particularly, predators may represent erroneous records or misuse of valid taxonomic names (Agarwala and Ghosh, 1988). The objective of this article is to enlist the natural enemies of calaphidine aphids along with their host plants in different states/union territories of India as such checklist provides an invaluable reference for taxonomists, researchers, academicians, conservation managers, and policymakers to their proper use in natural/biological control against these pests.

The present checklist is based on the primary data of published literature on predators and parasitoids, e.g. books, book chapters, journals, proceedings of conferences, and a few authentic theses available on Shodhganga (<https://shodhganga.inflibnet.ac.in>) up to September 30, 2024. The records of predators and parasitoids of the aphids without naming their specific prey species are excluded from this checklist. In most of the recent - past literature, there are several errors in the scientific names of the insects both predators/parasitoids as well as their preys/hosts (aphids) and their food plants because of their modified status and other nomenclatural decisions and clarification. The names of aphids, as well as plants that were misspelt in the original records have been corrected where we logically ascertain the intended species. In the present checklist, attempts have been made to provide the valid scientific names of the predators following GBIF (2024), WSC (2024), aphids following Favret (2024), and of the plants, following (WFO, 2024). For detailed synonymy of the valid species, the above references should be consulted.

RESULTS AND DISCUSSION

A. *Predators of calaphidine aphids*

The data displayed in Table 1 demonstrated that a total of 48 species of predators are recorded to prey on 17 species of calaphidine aphids out of 50 species recorded (Singh *et al.*, 2023). Predators of these species belong to one order of class Arachnida, the order Araneae (spiders) (3 families) and four orders of class Insecta: Coleoptera (family Coccinellidae), Diptera (family Syrphidae), Hemiptera (families Anthocoridae, Geocoridae) and Neuroptera (Chrysopidae, Hemerobiidae). The total number of these predator are species distributed in 16 states/union territories of India. The present checklist shows that the maximum number of predator species are recorded in Manipur (23 species, 36 triplets) followed by Jammu & Kashmir (11 species, 20 triplets), Uttarakhand (10 species, 13 triplets) and less than 10 species in rest of 13 states of India. Among the calaphidine aphids, *Tuberculatus paiki* Hille Ris Lambers, *Tuberculatus indicus* Ghosh, *Chromaphis juglandicola* (Kaltenbach) and *Taoia indica* (Ghosh and Raychaudhuri) attract 14, 13, 11, 11 and 10 species of predators, respectively (Table 2).

Table 1. Number of species of predators belonging to different taxa preying on calaphidine aphids infesting different number of host plants distributed in different states/union territories of India.

Class	Orders	Families of predators	Number of				
			Predator/parasitoid species	Prey/host species	Host plant species	Triplets	States/union territories
Predators							
Arachnida	Araneae	Linyphiidae	1	1	1	1	1
		Theridiidae	1	1	1	1	1
		Thomisidae	1	1	1	1	1
		Sub total	3	3	3	3	3
Insecta	Coleoptera	Coccinellidae	32	13	9	72	9
	Diptera	Syrphidae	5	5	5	9	8
	Hemiptera	Anthocoridae	1	1	1	1	1
		Geocoridae	1	1	1	1	1
		Sub total	2	2	2	2	2
	Neuroptera	Chrysopidae	4	5	6	8	3
		Coniopterygidae	1	1	1	1	1
		Hemerobiidae	2	2	2	2	2
		Sub total	7	6	6	11	4
	Total			48	17	13	96
Parasitoids							
Insecta	Hymenoptera	Aphelinidae	1	1	1	1	1
		Braconidae	15	11	9	15	7
		Total	16	12	3	3	3

1. Class: Arachnida, Order: Araneae

The order Araneae comprises spiders which are an extremely precious element of the earth's ecosystem being predatory devouring mostly insects and keeping their population under check (Nyffeler and Birkhofer, 2017). But, unlike insect predators, their potential as biocontrol agents is not exploited to its fullest. Recently, Singh *et al.* (2024a) reported 77 species of aphidophagous spiders in India preying on 53 species of aphids infesting 58 species of plants. Table 1 reveals that only 3 species of spiders belonging to 3 families are known to prey on different species of calaphidine aphids in India in 3 states as mentioned below. Indeed, minimal attempts have been made to record these aphidophagous spiders in India, and an intensive and extensive survey plan is warranted to record them in unexplored areas.

Family 1: Linyphiidae

1. *Linyphia* sp.

- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - West Bengal (Raychaudhuri *et al.*, 1979; Debnath, 2020)

Family 2: Theridiidae

1. *Theridion* sp.

- *Myzocallis (Globulicaudaphis) pakistanica* (Hille Ris Lambers, 1966)
- *Quercus* sp. - Himachal Pradesh (Das and Raychaudhuri, 1983)

Family 3: Thomisidae

1. *Indoxysticus minutus* (Tikader, 1960) [syn. *Xysticus minutus* Tikader, 1960]

- *Pterocallis (Pterocallis) affinis* Chakrabarti, 1988
- *Corylus colurna* L. - Uttarakhand (Debnath, 1991)

Table 2. Number of calaphidine aphids preyed by number of species of ladybird beetles, host plant species and triplets (predator - prey - host plant associations) and their distribution in India.

Aphid species	Number of predator species	Number of host plant species	Number of triplets	Number of states/union territories
<i>Betacallis sikkimensis</i>	4	1	4	1
<i>Chromaphis hirsutustibis</i>	2	2	2	1
<i>Chromaphis juglandicola</i>	11	1	11	2
<i>Clethrobium dryobius</i>	1	1	1	1
<i>Indiochaitophorus furcatus</i>	1	1	1	1
<i>Myzocallis pakistanica</i>	1	1	1	1
<i>Myzocallis polychaeta</i>	1	1	1	1
<i>Panaphis juglandis</i>	6	1	6	2
<i>Pterocallis affinis</i>	1	1	1	1
<i>Sarucallis kahawaluokalani</i>	2	2	2	1
<i>Takecallis affinis affinis</i>	1	1	1	1
<i>Taoia indica</i>	10	2	11	4
<i>Therioaphis ononidis</i>	1	1	1	1
<i>Therioaphis</i> sp.	11	1	11	9
<i>Therioaphis trifolii</i>	4	1	4	1
<i>Tuberculatus indicus</i>	13	1	13	2
<i>Tuberculatus nervatus</i>	7	1	7	1
<i>Tuberculatus paiki</i>	14	2	14	2
Total	48	13	96	16

2. Class: Insecta

Order 1: Coleoptera, Family: Coccinellidae

Among the Coleoptera, the aphidophagous ladybird beetles (Coccinellidae) are distributed throughout the world. Though several species of this family are major agricultural pests, at least 260 species are insectivorous feeding on soft insects like aphids, scale insects, mealy bugs, whiteflies etc. in India (Omkar and Pervez, 2004). Several species of these beetles have been used in classical and applied biocontrol of aphids and other soft insects (Kumar and Omkar, 2023). Table 1 demonstrates that 32 species of Coccinellidae feed the 13 species of calaphidine aphids infesting 9 species of host plants distributed in only 9 states/union territories of India with 72 predator-prey-food plant associations (triplets). Most of the species of these ladybird beetles are reported from Manipur (21 species) followed by Jammu & Kashmir (8 species), Karnataka (5 species triplets) and less than 5 species in other states/union territories. Among the calaphidine aphids, *Tuberculatus paiki* Hille Ris Lambers and *Tuberculatus indicus* Ghosh attract 14 and 13 species of coccinellids, respectively, only in Manipur and West Bengal states of India. Detail predator-prey-host plant records are given below.

1. *Adalia tetraspilota* (Hope, 1831)

- *Chromaphis juglandicola* (Kaltenbach, 1843)
 - *Juglans regia* L. - Uttarakhand (Ghosh *et al.*, 1991); Jammu & Kashmir (Khan and Shah, 2017; Gull and Rasheed, 2024)
- *Panaphis juglandis* (Goeze, 1778)
 - *Juglans regia* L. - Uttarakhand (Ghosh *et al.*, 1991)
- *Tinocallis* sp.
 - *Ulmus* sp. - Jammu & Kashmir (Khan and Shah, 2017)

2. *Alloneda dodecaspilota* (Hope, 1831) [syn. *Aiolocaria dodecaspilota* (Hope, 1831)]

- *Taoia indica* (Ghosh and Raychaudhuri, 1972)

- *Alnus nepalensis* D. Don - Manipur (Chakrabarti *et al.*, 2012)
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus* sp. - West Bengal (Ghosh and Raychaudhuri, 1982; Debnath, 2020)
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nitida* (Spach) Endl. - Manipur (Singh and Singh, 1985)
- *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus serrata* Murray - Manipur (Singh and Singh, 1985; Chakrabarti *et al.*, 2012)
- *Tuberculatus (Orienttuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
- *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
- 3. *Brumoides suturalis* (Fabricius, 1798) [syn. *Brumus suturalis* (Fabricius, 1798)]**
- *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
- *Medicago sativa* L. - Uttar Pradesh (Chaudhary and Singh, 2012)
- 4. *Calvia championorum* Booth, 1997**
- *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
- 5. *Calvia explanata* Poorani, 2014**
- *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017; Gull and Rasheed, 2024)
- *Panaphis juglandis* (Goeze, 1778)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - Sikkim (Joshi and Sangma, 2015)
- *Tinocallis* sp.
- *Ulmus* sp. - Jammu & Kashmir (Khan and Shah, 2017)
- 6. *Calvia sykesii* (Crotch, 1874)**
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - Sikkim (Joshi and Sangma, 2015)
- 7. *Cheilomenes sexmaculata* (Fabricius, 1781) [syn. *Menochilus sexmaculatus* (Fabricius, 1781)]**
- *Sarucallis kahawaluokalani* (Kirkaldy, 1907)
- Unknown plant - Tripura (Agarwala *et al.*, 1987)
- *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
- *Medicago sativa* L. - Gujarat (Patel, 2015); Karnataka (Megha *et al.*, 2015); Uttar Pradesh (Chaudhary and Singh, 2012)
- *Tuberculatus (Orienttuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
- *Quercus serrata* Murray - Manipur (Somen Singh *et al.*, 1995)
- *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
- 8. *Coccinella septempunctata* Linnaeus, 1758**
- *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017; Gull and Rasheed, 2024)
- *Myzocallis (Neodryomyzus) polychaeta* David, 1969
- *Quercus* sp. - Uttarakhand (Ghosh *et al.*, 1991)
- *Panaphis juglandis* (Goeze, 1778) - *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
- *Takecallis affinis affinis* Ghosh, 1986
- *Bambusa* sp. - Uttarakhand (Ghosh *et al.*, 1991)
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - Uttarakhand (Ghosh *et al.*, 1991); West Bengal (Ghosh and Raychaudhuri, 1982; Debnath, 2020)
- *Therioaphis ononidis* (Kaltenbach, 1846)

- Unknown aphid - Unknown plant (Agarwala and Ghosh, 1988)
 - *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
 - *Medicago sativa* L. - Uttar Pradesh (Chaudhary and Singh, 2012)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985); West Bengal (Chakrabarti *et al.*, 2012)
- 9. *Coccinella transversalis* Fabricius, 1781**
- *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
 - *Medicago sativa* L. - Karnataka (Megha *et al.*, 2015); Uttar Pradesh (Chaudhary and Singh, 2012)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - Unknown plant - India (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
- 10. *Cryptogonus bimaculatus* Kapur, 1948**
- *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985; Chakrabarti *et al.*, 2012)
- 11. *Harmonia dimidiata* (Fabricius, 1781)**
- *Chromaphis juglandicola* (Kaltenbach, 1843)
 - *Juglans regia* L. - Jammu & Kashmir (Gull and Rasheed, 2024)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Shantibala, 1989)
 - *Tuberculatus (Orienttuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
 - Unknown plant - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
- 12. *Harmonia eucharis* (Mulsant, 1853)**
- *Chromaphis juglandicola* (Kaltenbach, 1843)
 - *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017; Gull and Rasheed, 2024)
 - *Panaphis juglandis* (Goeze, 1778)
 - *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
 - Unknown plant - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Shantibala, 1989; Singh *et al.*, 1985)
- 13. *Harmonia octomaculata* (Fabricius, 1781)**
- *Therioaphis (Pterocallidium) trifolii trifolii* (Monell, 1882)
 - *Medicago sativa* L. - Karnataka (Megha *et al.*, 2015)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
- 14. *Hippodamia convergens* Guérin - Méneville, 1842**
- *Chromaphis juglandicola* (Kaltenbach, 1843)
 - *Juglans regia* L. - Jammu & Kashmir (Ahmad and Wani, 2014)
 - *Panaphis juglandis* (Goeze, 1778)
 - *Juglans regia* L. - Jammu & Kashmir (Ahmad and Wani, 2014)

15. ***Hippodamia variegata* (Goeze, 1777) [syn. *Adonia variegata* (Goeze, 1777)]**
 - *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
 - *Therioaphis (Pterocallidium) trifolii trifolii* (Monell, 1882)
- *Medicago sativa* L. - Karnataka (Megha *et al.*, 2015)
 - *Tinocallis* sp.
- *Ulmus* sp. - Jammu & Kashmir (Khan and Shah, 2017)
16. ***Micraspis discolor* (Fabricius, 1798) [syn. *Verania discolor* (Fabricius, 1798)]**
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Shantibala, 1989)
17. ***Micraspis vincta* (Gorham, 1895)**
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
18. ***Oenopia conglobata* (Linnaeus, 1758)**
 - *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Gull and Rasheed, 2024)
19. ***Oenopia kirbyi* Mulsant, 1850**
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
20. ***Oenopia manipurensis* Devi, Singh and Singh, 1991**
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Shantibala, 1989)
21. ***Oenopia mimica* Weise, 1902**
 - *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - Sikkim (Joshi and Sangma, 2015)
22. ***Oenopia quadripunctata* Kapur, 1963**
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Orienttuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
- *Quercus serrata* Murray - Manipur (Singh *et al.*, 1993)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985)
23. ***Oenopia sauzeti* Mulsant, 1866**
 - *Clethrobium dryobius* Chakrabarti and Raychaudhuri, 1976
- *Prunus cerasus* L. - Sikkim (Chakrabarti *et al.*, 2012)
24. ***Oenopia sexareata* (Mulsant, 1853) [syn. *Coelophora sexarcata* Mulsant, 1853]**
 - *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - West Bengal (Raychaudhuri *et al.*, 1978; Ghosh and Raychaudhuri, 1982)
 - *Tuberculatus (Orienttuberculoides) paiki* Hille Ris Lambers, 1974
- *Quercus semiserrata* Roxb. - Manipur (Shantibala, 1989)
25. ***Phrynocaria unicolor* (Fabricius, 1792) [syn. *Coelophora unicolor* (Fabricius, 1792)]**
 - *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus* sp. - Manipur (Chakrabarti *et al.*, 2012)
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus serrata* Murray - West Bengal (Chakrabarti *et al.*, 2012)
26. ***Propylea dissecta* (Mulsant, 1850)**
 - *Therioaphis (Pterocallidium) trifolii trifolii* (Monell, 1882)

- *Medicago sativa* L. - Karnataka (Megha *et al.*, 2015)
- 27. ***Propylea luteopustulata* (Mulsant, 1850) [syn. *Oenopia luteopustulata* Mulsant, 1850; *Pania luteopustulata* (Mulsant, 1850)]**
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)
- 28. ***Scymnus (Pullus) giganteus* Kamiya, 1961**
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - Unknown aphid - Unknown plant (Chakrabarti *et al.*, 2012)
- 29. ***Scymnus (Pullus) hilaris* Motschulsky, 1858**
 - ***Tuberculatus (Orientotuberculoides) paiki* Hille Ris Lambers, 1974**
 - *Quercus serrata* Murray - Manipur (Singh *et al.*, 1985; Chakrabarti *et al.*, 2012)
- 30. ***Scymnus (Scymnus) nubilus* Mulsant, 1850**
 - *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
 - Unknown aphid - Unknown plant - (Chakrabarti *et al.*, 2012)
- 31. ***Scymnus* sp.**
 - *Taoia indica* (Ghosh and Raychaudhuri, 1972)
 - *Alnus nepalensis* D. Don - Manipur (Agarwala *et al.*, 1980; Chakrabarti *et al.*, 2012)
- 32. ***Synonycha grandis* (Thunberg, 1781)**
 - *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
 - *Quercus serrata* Murray - Manipur (Chakrabarti *et al.*, 2012)

Order 2: Diptera, Family: Syrphidae

Among the Diptera, the Syrphidae, commonly known as hover flies, are the most common aphid predators and are widely distributed throughout the world. Most of the syrphids provide dual service in nature, as an adult they help in crop pollination (Joshi *et al.*, 2023) and as larvae, they consume several soft-bodied insects such as aphids, scale insects, mealy bugs, whiteflies, thrips etc.; and thus form an integral part of natural control of these insects (Kumar and Omkar, 2023). Table 1 demonstrates that only 5 species of hover flies feed the 5 species of calaphidine aphids infesting 5 species of host plants distributed in only 8 states/union territories of India with 9 predator-prey-food plant associations (triplets). Detail predator-prey-host plant records are given below.

1. ***Allograpta javana* (Wiedemann, 1824) [syn. *Sphaerophoria javana* Wiedemann, 1824; *Syrphus javana* Wiedemann, 1824]**
 - *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
 - *Medicago sativa* L. - Assam (Agarwala *et al.*, 1984); Bihar (Agarwala *et al.*, 1984); Karnataka (Ghorpadé, 1973); Meghalaya (Agarwala *et al.*, 1984); Tamil Nadu (Agarwala *et al.*, 1984)
2. ***Episyrphus balteatus* (De Geer, 1776) [syn. *Syrphus balteatus* De Geer, 1776]**
 - *Indiochaitophorus furcatus* Verma, 1970
 - *Ulmus wallichiana* Planch. (syn. *Ulmus laevigata* Royle) - Jammu Kashmir (Bhagat and Lone, 1984)
3. ***Eupeodes confrater* (Wiedemann, 1830) [syn. *Metasyrphus confrater* (Wiedemann, 1930)]**
 - *Tuberculatus (Orientotuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
 - *Quercus serrata* Murray - Manipur (Somen Singh *et al.*, 1995)
4. ***Eupeodes latifasciatus* (Macquart, 1829) [syn. *Metasyrphus latifasciatus* (Macquart, 1829)]**
 - *Chromaphis juglandicola* (Kaltenbach, 1843)
 - *Juglans regia* L. - Jammu & Kashmir (Gull and Rasheed, 2024)
5. ***Ischiodon scutellaris* (Fabricius, 1805) [syn. *Xanthogramma scutellare* (Fabricius, 1805)]**
 - *Sarucallis kahawaluokalani* (Kirkaldy, 1907)
 - Unknown plant - Tripura (Agarwala *et al.*, 1987)

Order 3: Hemiptera

The order Hemiptera includes at least 7 families of predatory bugs preying on aphids, scale insects, mealybugs, bugs, leaf hoppers, thrips, mites, caterpillars etc. (Chellappan and Ranjith, 2023). In India, members of 2 families, Anthocoridae and Geocoridae, one species each, are recorded as predators of calaphidine aphids in Uttarakhand and Rajasthan, respectively (Table 1) as mentioned below.

Family 1: Anthocoridae

1. Orius bifilarus Ghauri, 1972

- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don Uttarakhand (Debnath, 1991)

Family 2: Geocoridae

2. Geocoris jucundus (Fieber, 1861)

- *Therioaphis (Pterocallidium) trifolii* (Monell, 1882)
- *Medicago sativa* L. - Rajasthan (Pal, 1974)

Order 4: Neuroptera

Neuroptera includes lacewings, mantisflies, antlions and their relatives and both adults and larvae are entomophagous. They are globally distributed and generalist predators of soft-bodied insects. Recently, Singh *et al.* (2024b) enlisted 32 species of aphidophagous neuropterans from India belonging to 4 families. However, members of only three families, Chrysopidae (green lacewings), Coniopterygidae (dustywings) and Hemerobiidae (brown lacewings) are recorded to prey on calaphidine aphids in India. Among the chrysopids, commonly known as green lacewings, only 4 species prey on 5 species of calaphidine aphids feeding on 6 species of food plants distributed mostly in Uttarakhand states of India. Only a single species of dustywing and two species of brown lacewings are in India as mentioned below.

Family 1: Chrysopidae

1. Chrysopa himalayana Ghosh, 1985

- *Chromaphis hirsutustibis* Kumar and Lavigne, 1970
- *Juglans regia* L. - Uttarakhand (Debnath *et al.*, 1988)

2. Chrysoperla zastrowi sillemi (Esben - Petersen, 1935) [syn. Chrysopa gujaratensis Ghosh, 1976; Chrysopa punensis Ghosh, 1976; Chrysopa sanandensis Ghosh, 1977; Chrysopa sillemi Esben - Petersen, 1935]

- *Betacallis sikkimensis* Basu, Ghosh and Raychaudhuri, 1974
- *Betula alnoides* Buch.–Ham. - Uttarakhand (Dey, 2015)
- *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
- *Panaphis juglandis* (Goeze, 1778)
- *Juglans regia* L. - Jammu & Kashmir (Khan and Shah, 2017)
- *Therioaphis (Pterocallidium) trifolii trifolii* (Monell, 1882)
- *Medicago sativa* L. - Maharashtra (Tambe and Kadam, 2015)
- *Tinocallis* sp.
- *Ulmus* sp. - Jammu & Kashmir (Khan and Shah, 2017)

3. Pseudomallada alcestes (Banks, 1911) [syn. Mallada alcestes (Banks, 1911)]

- *Betacallis sikkimensis* Basu, Ghosh and Raychaudhuri, 1974
- *Betula alnoides* Buch.–Ham. - Uttarakhand (Dey, 2015)

4. Retipenna dasyphlebia (McLachlan, 1894) [syn. Chrysopa dasyphlebia McLachlan, 1894]

- *Betacallis sikkimensis* Basu, Ghosh and Raychaudhuri, 1974
- *Betula alnoides* Buch.–Ham. - Uttarakhand (Debnath *et al.*, 1988; Dey, 2015)

Family 2: Coniopterygidae

1. Coniocompsa indica Withycombe, 1925

- *Chromaphis hirsutustibis* Kumar and Lavigne, 1970

- *Berberis* sp. - Uttarakhand (Dey, 2015)

Family 3: Hemerobiidae

2. *Micromus timidus* Hagen, 1853

- *Tuberculatus (Orientotuberculoides) nervatus* Chakrabarti and Raychaudhuri, 1976
- *Quercus serrata* Murray - Manipur (Somen Singh *et al.*, 1995)

3. *Micromus* sp.

- *Betacallis sikkimensis* Basu, Ghosh and Raychaudhuri, 1974
- *Betula alnoides* Buch.–Ham. - Uttarakhand (Debnath, 1991)

B. Parasitoids of calaphidine aphids

The parasitoids of the calaphidine aphids belong to two families of the order Hymenoptera: Aphelinidae (only subfamily Aphelininae, tribe Aphelinini) and Braconidae (only subfamily Aphidiinae). A total of 16 species of parasitoids belonging to different taxa were observed to parasitise 15 species of these aphids on 11 food plant species distributed in 7 states/union territories of India (Table 1).

The Aphelinidae are a small group of Chalcidoidea (Hymenoptera) containing 32 genera and a little over a thousand species (Hayat, 1998) and is a major source of biocontrol agents of economically important insect pest species such as coccoids, aphids and aleyrodids (Homoptera). Aphelinidae is represented by a single species, *Aphelinus argiope* Walker while

Table 3. Number of species of aphidiine parasitoids parasitising the number of host aphids calaphidine aphids host plants infested, number of tritrophic associations and their distribution in India

Aphid species	Number of parasitoid species	Number of host plants	Number of triplets	Distribution in states/union territories
1. <i>Betacallis querciphaga</i>	1	2	2	1
2. <i>Betacallis sikkimensis</i>	1	1	1	1
<i>Betacallis</i> sp.	1	1	1	1
3. <i>Chromaphis juglandicola</i>	1	1	1	1
4. <i>Myzocallis ulmifoliae</i>	1	1	1	1
5. <i>Panaphis juglandis</i>	2	1	2	3
6. <i>Saltusaphis</i> sp.	1	1	1	1
7. <i>Shivaphis celti</i>	4	2	4	2
<i>Shivaphis</i> sp.	1	1	1	1
8. <i>Takecallis affinis</i>	2	1	2	2
9. <i>Takecallis arundinariae</i>	1	1	1	2
10. <i>Taoia indica</i>	1	1	1	2
11. <i>Therioaphis trifolii</i>	1	1	1	1
<i>Therioaphis</i> sp.	1	1	1	1
12. <i>Tuberculatus indicus</i>	1	1	1	1
Total	15	11	15	7

Das and Chakrabarti (2023) listed 157 aphidiine species parasitising several aphid species in India. Out of these, only 15 species are described/recorded from India parasitising 15 species of the calaphidine aphids (in addition, 3 aphids are identified up to generic level only) infesting 11 species of host plants (in addition, 3 unknown species) distributed only in 7 states/union territories of India. All these parasitoids parasitise only 1-2 aphid species. The maximum number of parasitoids was recorded on *Shivaphis* (*Shivaphis*) *celti* Das (4 species of braconid parasitoids) in India (Table 3). It indicates that India has very limited fauna and biodiversity of parasitoids of the calaphidine aphids of economic importance. It demonstrates that survey programmes should be conducted regarding the biodiversity of parasitoids of these aphids in unexplored areas. Following checklist displays the species of aphidiine parasitoids recorded/described parasitising the calaphidine in India.

The following is the checklist of aphid parasitoids along with their host aphids infesting various food plants in different states/union territories of India is mentioned below.

Family 1: Aphelinidae, subfamily: Aphelininae

1. *Aphelinus argiope* Walker, 1839 [syn. *Mesidia argiope* (Walker, 1839)]

- *Saltusaphis* sp.
- Unknown plant - Uttar Pradesh (Hayat, 1979)

Family 2: Braconidae, subfamily: Aphidiinae

1. *Aphidius matricariae* Haliday, 1834

- *Myzocallis* (*Myzocallis*) *ulmifoliae* Shinji, 1954
- *Rubia cordifolia* L. - Jammu & Kashmir (Bhagat and Ahmad, 1991)

2. *Betuloxys assamensis* (Stary, 1975) [syn. *Trioxys* (*Betuloxys*) *assamensis* Stary, 1975]

- *Betacallis querciphaga* Basu, Ghosh and Raychaudhuri, 1974
- *Quercus* sp. - Meghalaya (Ghosh and Raychaudhuri, 1982)
- Unknown plant - Meghalaya (Starý and Ghosh, 1975)

3. *Betuloxys takecallis* (Stary, 1978) [syn. *Trioxys* (*Betuloxys*) *takecallis* Starý, 1978; *Trioxys takecallis* Starý, 1978]

- *Takecallis arundinariae* (Essig, 1917)
- *Bambusa* sp. - Meghalaya (Raychaudhuri *et al.*, 1979); West Bengal (Starý and Raychaudhuri, 1978)

4. *Binodoxys jaii* (Bhagat, 1982) [*Trioxys jaii* Bhagat, 1982]

- *Shivaphis* (*Shivaphis*) *celti* Das, 1918
- *Celtis australis* L. - Jammu & Kashmir (Bhagat, 1982)

5. *Binodoxys manipurensis* Singh PM and Singh, 1986

- *Shivaphis* (*Shivaphis*) *celti* Das, 1918
- *Celtis tetrandra* Roxb. - Manipur (Singh and Singh, 1986)

6. *Binodoxys takecallis* (Das and Chakrabarti, 1989)

- *Takecallis affinis affinis* Ghosh, 1986 [syn. *Takecallis himalayensis* Chakrabarti, 1988]
- *Bambusa* sp. - Himachal Pradesh (Chakrabarti and Debnath, 2009); Uttarakhand (Das and Chakrabarti, 1989a; Chakrabarti and Debnath, 2009)

7. *Ephedrus lacertus* (Haliday, 1833)

- *Takecallis affinis affinis* Ghosh, 1986 [syn. *Takecallis himalayensis* Chakrabarti, 1988]
- *Bambusa* sp. - Himachal Pradesh (Chakrabarti and Debnath, 2009); Uttarakhand (Das and Chakrabarti, 1989a; Sarkar, 2022)

8. *Lipolexis gracilis* Forster, 1862

- *Therioaphis* (*Pterocallidium*) *trifolii* (Monell, 1882)
- Unknown plant - Jammu & Kashmir (Starý and Ghosh, 1983; Chakrabarti and Debnath, 2009)

9. *Praon himalayensis* Das and Chakrabarti, 1989

- *Panaphis juglandis* (Goeze, 1778)
- *Juglans regia* L. - Himachal Pradesh (Chakrabarti and Debnath, 2009); Uttarakhand (Das and Chakrabarti, 1989b; Sarkar, 2022)

10. Toxares deltiger (Haliday, 1833)

- *Betacallis sikkimensis* Basu, Ghosh and Raychaudhuri, 1974
- *Conium maculatum* L. - Jammu & Kashmir (Chakrabarti and Debnath, 2009)
- *Betacallis* sp.
- *Conium maculatum* L. - Jammu & Kashmir (Bhagat, 1983); Jammu & Kashmir (Bhagat, 1984)

11. Trioxys complanatus Quilis, 1931

- *Therioaphis* sp.
- *Vicia sativa* L. - Jammu & Kashmir (Bhagat, 1984)

12. Trioxys pallidus (Haliday, 1833)

- *Chromaphis juglandicola* (Kaltenbach, 1843)
- *Juglans regia* L. - Jammu & Kashmir (Shuja-Uddin, 1982; Ahmad and Wani, 2014)
- *Panaphis juglandis* (Goeze, 1778)
- *Juglans regia* L. - Jammu & Kashmir (Ahmad and Wani, 2014; Khan and Shah, 2017)

13. Trioxys raychaudhurii Bhagat, 1990

- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - Meghalaya (Raychaudhuri *et al.*, 1990)
- *Taoia indica* (Ghosh and Raychaudhuri, 1972)
- *Alnus nepalensis* D. Don - West Bengal (Tamili, 1988)

14. Trioxys shivaphis Takada, 1966

- *Shivaphis (Shivaphis) celti* Das, 1918
- *Celtis australis* L. - Jammu & Kashmir (Bhagat, 1984)

15. Trioxys soporensis Shuja-Uddin, 1982

- *Shivaphis (Shivaphis) celti* Das, 1918
- *Celtis* sp. - Jammu & Kashmir (Chakrabarti and Debnath, 2009)
- *Shivaphis* sp.
- *Celtis* sp. - Jammu & Kashmir (Shuja-Uddin, 1982)

16. Trioxys sp.

- *Tuberculatus (Acanthotuberculatus) indicus* Ghosh, 1972
- *Quercus griffithii* Hook.f and Thoms. ex Miq. - Meghalaya (Starý and Ghosh, 1978)

CONCLUSION

The calaphidine aphids are highly economically important infesting different food plants of economic importance such as beeches, cashews, walnuts etc. in India. In nature, its population is regulated by their natural enemies. In this checklist, 48 species of predators and 15 species of parasitoids of these aphids are listed which are distributed in 16 and 7 states/union territories of India. Indeed, very few attempts have been made to record these natural enemies in India, and an intensive and extensive survey plan is warranted to record them in unexplored areas.

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