

A catalogue of tri-trophic associations of arthropod predators of aphids (Homoptera: Aphididae) in different districts of Himachal Pradesh, India

Rajendra Singh¹, Anuradha Shukla²

¹Department of Zoology, Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur, U.P., India. E-mail: rsinghgpu@gmail.com, ORCID ID: 0000-0002-7296-9860

²Department of Zoology, Jhun Jhun Wala P. G. College, Faizabad, Ayodhya - 224001, Uttar Pradesh, India. E-mail: anuradhazoology27@gmail.com, ORCID ID: 0009-0002-9325-9443

*Corresponding author: rsinghgpu@gmail.com

Received 21 January 2026 | Accepted 29 April 2026 | Published 04 June 2026

Abstract

The study presents a comprehensive synthesis of aphidophagous predator diversity and their tri-trophic associations (predator-aphid-host plant) across the agroecological zones of Himachal Pradesh. A total of 85 predator species, encompassing various arthropod taxa, were documented preying on 73 aphid species infesting 75 host plants, forming 378 distinct associations across 10 districts. Among the insect predators, Coccinellidae emerged as the most dominant group (39 species, 218 associations), followed by Syrphidae (22 species, 113 associations) and Neuroptera (7 species, 21 associations). Generalist species such as *Coccinella septempunctata*, *Episyrphus balteatus*, and *Chrysoperla zastrowi sillemi* displayed wide prey ranges and broad geographical distributions, indicating their ecological versatility and significance in aphid suppression. Non-insect predators, particularly spiders (16 species across nine families), contributed 27 tri-trophic associations from six districts, with Thomisidae being the most species-rich family. Spatially, Solan, Kangra, and Shimla districts supported the highest number of associations, reflecting their diverse cropping systems and favourable climatic conditions. High-altitude regions such as Kinnaur and Lahaul & Spiti also harboured notable predator diversity, demonstrating the adaptability of aphidophagous guilds to extreme environments. Overall, the findings reveal a highly structured and ecologically resilient predator community, dominated by generalist taxa that function across diverse habitats and elevations. This dataset provides crucial baseline information for biodiversity conservation. It highlights the potential of native aphidophagous predators in developing sustainable, region-specific Integrated Pest Management strategies for the temperate and sub-temperate agroecosystems of Himachal Pradesh.

key words: Aphid, biological control, checklist, Coccinellidae, Neuroptera, Syrphidae, tri-trophic associations, Himachal Pradesh, Sea.

1. Introduction

Tri-trophic interactions constitute a fundamental framework of terrestrial food webs, integrating primary producers, herbivorous insects such as aphids, and their associated natural enemies. These interactions are pivotal for elucidating patterns of biodiversity, community organization, and ecosystem functioning (Singh & Singh, 2016). In aphid-centered systems, host plants act as primary resource bases, sustaining aphid populations that subsequently support a diverse assemblage of aphidophagous natural enemies, including spiders (Araneae), coccinellid beetles (Coleoptera), syrphid flies (Diptera), lacewings (Neuroptera), and predatory bugs (Omkar, 2023). Together, these predators regulate aphid populations and maintain ecological stability. Aphidophagous predators play a crucial role as biological control agents due to their adaptability and feeding efficiency. Generalist predators like *Coccinella septempunctata*, *Cheilomenes sexmaculata*, and *Hippodamia variegata*, along with syrphids such as *Episyrphus balteatus* and *Ischiodon scutellaris*, and chrysopids like *Chrysoperla zastrowi sillemi*, significantly suppress aphid populations and support integrated pest management (IPM) (Omkar, 2023). Their activity reduces reliance on chemical insecticides and promotes sustainable agriculture.

The effectiveness of these interactions depends on plant traits, aphid dynamics, and predator behaviour. Plant morphology and volatiles influence predator attraction and efficiency, while environmental factors such as temperature and humidity regulate their population dynamics (Dixon, 2000; Hodek et al., 2012). Understanding these factors is essential for predicting predator-prey relationships and improving pest management strategies. Regional variation in tri-trophic associations is pronounced due to differences in climate, vegetation, and land use. Studies conducted across different regions of India, including northern states such as Jammu and Kashmir (Singh & Bhagat, 2026; Singh et al., 2025), Uttarakhand (Singh & Omkar, 2025; Singh, 2026a), and Uttar Pradesh (Singh, 2025a); eastern regions like West Bengal (Singh & Shukla, 2026a) and Manipur (Singh, 2026b); western India (Gujarat, Singh & Shukla, 2026b), and southern states such as Karnataka (Singh & Agrawal, 2026) and Kerala (Singh & Shukla, 2026c), reveal pronounced spatial variation in predator assemblages. For example, northern regions are typically dominated by *Coccinella septempunctata* and *Episyrphus balteatus*, whereas southern regions more commonly support species such as *Cheilomenes sexmaculata* and *Micraspis discolor*, reflecting differences in altitudes, climatic conditions, vegetations etc.

Comprehensive cataloguing of tri-trophic associations provides critical insights into species diversity, host specificity, and ecosystem stability (Emden & Harrington, 2007). Such inventories aid in identifying effective natural enemies, guiding biological control programs, and designing habitat management strategies. They also serve as indicators of environmental health and ecosystem change (Andersen, 1999; Iperiti & Paoletti, 1999).

Aphids (Hemiptera: Aphididae), with over 794 species in India, including ~250 of agricultural importance, are major pests due to rapid reproduction, polyphagy, and virus transmission (Singh & Singh, 2022). Therefore, region-specific tri-trophic checklists are essential for developing sustainable pest management strategies. The present study provides a comprehensive checklist of aphid-plant-predator associations from Himachal Pradesh, offering baseline data on species diversity, distribution, and host relationships. This information serves as a valuable resource for ecological research and the development of sustainable pest management programs.

2. Materials and methods

2.1 Study area

Himachal Pradesh (latitude: 30°22' to 33°12'N, longitude: 75°47' to 79°04'E) is a northwestern Indian state located in the Western Himalayas, with a total geographical area of 55,673 km² and spread across valleys featuring several peaks, many of which are surrounded by perennial rivers flowing through them. Himachal Pradesh shares borders with Jammu & Kashmir and Ladakh to the north, Punjab to the west, Haryana to the southwest, Uttarakhand to the southeast, a very narrow border with Uttar Pradesh to the south and China (Tibet Autonomous Region) to the east (Figure 1). In 1966, portions of Punjab, comprising Simla, Kangra, Kullu, and Lahaul & Spiti districts; the Lohara, Amb, and Una Kanungo circles; parts of the Santokhgarh Kanungo circle and certain areas of Una tehsil in Hoshiarpur district; as well as the Kandaghat and Nalagarh tehsils and parts of the Dhar Kalan Kanungo circle of Pathankot district, were merged into Himachal Pradesh. The state's drainage system is characterised by a network of perennial rivers originating from glaciers and sustained by both snowmelt and rainfall, forming part of the Indus and Ganges river basins. Major rivers include the Chenab, Ravi, Beas, Sutlej, and Yamuna. Climatically, Himachal Pradesh exhibits considerable diversity—from hot and humid subtropical conditions in the southern regions to cold alpine and glacial climates in the higher northern and eastern mountain ranges. Approximately 66.5% of the state's total area is under forest cover, supporting a rich biodiversity of flora and fauna. The landscape is dotted with orchards, meadows, pastures, wildlife sanctuaries, and national parks, while administratively the state is divided into 12 districts (Figure 1).

The present checklist of tri-trophic associations involving aphidophagous arthropods in Himachal Pradesh was compiled through an extensive review of published literature, including books, peer-reviewed journal articles, authenticated theses, and reliable online databases available up to 31 October 2025. Relevant records documenting associations among predators, aphids, and host plants were systematically extracted and organised. Records of aphid predators lacking information on both prey (aphid species) and host plant species were excluded from the dataset. Earlier records, including some recent publications, were carefully scrutinized due to potential taxonomic inconsistencies arising from ongoing revisions, synonymies, and misidentifications. Given the rapid advancement in taxonomic research and frequent updates in nomenclature, all species names were verified and standardised using authoritative databases. Aphid taxonomy was validated following the Aphid Species File (<https://aphid.speciesfile.org>), host plant nomenclature was updated according to World Flora Online (<https://www.worldfloraonline.org>), and arthropod classification was cross-checked using the Global Biodiversity Information Facility (<https://www.gbif.org>). Only those records with reliable identification and clearly defined tri-trophic relationships (predator–aphid–host plant) were included in the final dataset to ensure accuracy and consistency.

As this study is based on the compilation of previously published literature, the available records lacked consistent quantitative parameters such as abundance, frequency, and sampling effort. Consequently, the dataset did not support the reliable calculation of diversity indices or the application of robust statistical and network analyses. Therefore, such analyses were not undertaken in order to avoid the introduction of assumptions that could compromise the scientific rigour and accuracy of the study.

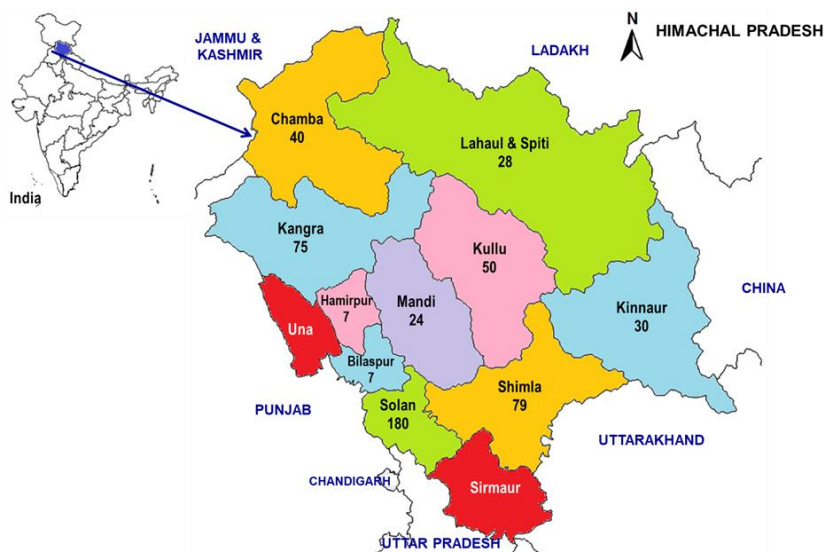


Figure 1. Number of tri-trophic associations (triplets) of aphidophagous arthropod predators in different districts of Himachal Pradesh. No record is available in red shaded districts.

3. Results & Discussion

A review of literature indicates that Rahman (1940) first documented tri-trophic interactions of aphidophages in Himachal Pradesh, reporting two hover fly species and one dustywing. Subsequent contributions by Rao (1969), Siddiqui & Krishnaswamy (1972), Hameed et al. (1975), and Verma & Chowdhuri (1975) expanded records of aphidophagous hover flies and coccinellids. During the 1980s, studies by Agarwala et al. (1981, 1984), Poddar (1982), and Das & Raychaudhuri (1983) documented diverse spiders, ladybirds, and syrphids across agricultural and horticultural systems. Further enrichment occurred in the 1990s through works by Bhardwaj (1991), Gupta & Bhalla (1993), Lakhanpal & Raj (1998), and others, reporting numerous predator–aphid associations. In the 21st century, extensive studies (Poorani, 2002; Sharma & Kashyap, 2002; Verma et al., 2005; Kumari et al., 2006; Sood et al., 2007; Sharma et al., 2009–2020; Thakur & Chandla, 2013; Dixit et al., 2019; Singh et al., 2020) added several new records, particularly from Solan district. Recent investigations (Ankita et al., 2021; Kumari et al., 2021a, b, 2024; Soni et al., 2021; Gaikwad et al., 2022; Chandana et al., 2023; Kasi & Waiba, 2023; Palial et al., 2023; Semwal et al., 2024) have further refined knowledge on taxonomy, host range, and ecological roles, providing a comprehensive understanding of aphidophagous arthropod diversity in the region.

The study documents aphidophagous predator diversity and their tri-trophic associations (predator–aphid–host plant) across agroecosystems of Himachal Pradesh, recording 87 predator species, 73 aphid species, and 75 host plants, forming 378 interactions across 10 districts (Table 1).

Table 1. Number of species of predators belonging to different taxa preying on different number of aphid species infesting different number of host plant species and triplets in Himachal Pradesh.

Class/Order/Family of the aphidophagous predators	Number of				
	Predator species	Aphid species	Plant species	Triplets	Districts
Class: Arachnida					
Araneae: 9 families	16	22	18	27	6
Class: Insecta					
Coleoptera: Coccinellidae	39	50	55	218	10
Dermaptera: Forficulidae	1	1	1	1	1
Diptera: Syrphidae	21	33	37	110	10
Hemiptera: Anthocoridae	1	1	1	1	1
Neuroptera: Chrysopidae	5	5	9	18	10
Neuroptera: Coniopterygidae	1	1	1	1	1
Neuroptera: Hemerobiidae	1	2	1	2	2
Total	85	73	75	378	10

All the predators belong to one order of class Arachnida, the order Araneae (9 families: Araneidae, Clubionidae, Dictynidae, Oxyopidae, Philodromidae, Tetragnathidae, Theridiidae, Thomisidae, Uloboridae); 5 orders of class Insecta: Coleoptera (Coccinellidae), Dermaptera (Forficulidae), Diptera (Syrphidae), Hemiptera (Anthocoridae), and Neuroptera (Chrysopidae, Coniopterygidae, Hemerobiidae) (Table 1). The distribution of aphidophagous predators across districts of Himachal Pradesh shows a clear relationship with altitudinal gradients and associated vegetation types, reflecting habitat heterogeneity and resource availability. In the mid-hill zone (≈ 900 – 2000 m), districts such as Solan, Kangra, and Shimla exhibited the highest diversity and interaction frequencies. Solan, with 180 tri-trophic associations, represents the primary hotspot, likely due to its subtropical to sub-temperate climate and intensively cultivated mosaic landscapes comprising brassica fields, solanaceous crops, cereals, and fruit orchards. Such vegetation supports high aphid abundance and continuous floral resources, favouring dominant aphidophages, particularly Coccinellidae and Syrphidae, which together contributed the majority of the 218 and 113 associations, respectively. Similarly, Kangra (75 associations) and Shimla (79 associations) benefit from diverse agro-horticultural systems and moderate climatic conditions, promoting both aphid proliferation and predator establishment. In contrast, the high-altitude districts (>2500 m), including Kinnaur (30 associations) and Lahaul and Spiti (28 associations) (Fig. 1), despite harsh climatic conditions, also supported notable predator diversity (Table 1). These regions are characterised by temperate to cold desert vegetation, sparse cropping (e.g., apple orchards, barley, and limited vegetables), and shorter growing seasons. The relatively lower but significant number of associations indicates that aphidophagous predators, particularly adaptable groups like coccinellids and spiders (notably Thomisidae and Araneidae), persist under constrained ecological conditions, exploiting seasonal aphid outbreaks.

The contribution of lacewings (Chrysopidae, Hemerobiidae, Coniopterygidae), though moderate (21 associations), was more evenly distributed across altitudes, reflecting their ecological plasticity. Dermaptera and Hemiptera, along with arachnid predators (16 species, 27 associations), formed minor yet ecologically important components, often associated with structurally complex vegetation such as orchards and forest margins. Overall, the pattern indicates that mid-altitude agroecosystems with diverse vegetation and intensive cultivation harbour the highest aphidophagous diversity, while high-altitude regions sustain specialized but resilient predator communities. This altitudinal gradient underscores the role

of vegetation complexity, cropping intensity, and climatic moderation in shaping predator-aphid-plant interactions across Himachal Pradesh.

Most the aphidophagous species in Himachal Pradesh are predatory on *Brassicorhynae brassicae* (26 predators species) on brassica vegetables (cabbage, cauliflower, kale) and oilseeds, followed by *Myzus persicae* (25 predators species) on brassica crops, potatoes; *Eriosoma lanigerum* (22 predador species) on apples and peaches, *Brachycaudus helichrysi* (16 predator species) on peaches; *Aphis pomi* (13 predator species) on apples, *Lipaphis erysimi* (3 predator species) on mustard, radish etc. and others supports 1-12 species of predators on several crop and wild plants.

Among the recorded host plants, *Brassica oleracea* varieties (cabbage, cauliflower, kale) (49 triplets) harboured the highest diversity of aphid predators followed by *Malus domestica* (apple) (30 triplets), and *Triticum aestivum* (wheat) (19 triplets). The remaining host plants sustained between 1 and 16 tri-trophic associations.

The study reveals a diverse and functionally rich assemblage of aphidophagous predators in Himachal Pradesh’s agroecosystems, reflecting a complex trophic network. Coccinellidae and Syrphidae emerged as the dominant groups, highlighting their key role in natural aphid regulation, while the presence of multiple other predator taxa indicates a multi-guild structure supporting ecological stability. This comprehensive documentation provides an essential baseline for assessing predator diversity, prey associations, and host-plant linkages, offering valuable insights for biodiversity conservation and the formulation of region-specific Integrated Pest Management strategies in Himachal Pradesh.

A. Class: Arachnidae, Order Araneae

The order Araneae comprises spiders, important insect predators that contribute to population regulation but remain relatively understudied in biological control. Singh et al. (2024a) reported 79 aphidophagous spider species in India associated with 53 aphid species and 59 host plants. In Himachal Pradesh, however, only 16 species from nine families were recorded across six districts (mainly Kullu and Shimla), associated with 22 aphid species on 18 host plants, forming 27 tri-trophic interactions (Table 2). Among the families, Thomisidae showed the highest species richness (5 species), followed by Araneidae (3 species). Other families were represented by one or two species.

Table 2. Number of species of aphidophagous spiders belonging to different families preying on different number of aphid species infesting different number of host plant species and triplets in Himachal Pradesh.

Families	Species of predators	Number of			
		Species of aphid	Species of host plant	Triplets	Districts
Araneidae	1. <i>Araneus</i> sp.	2	2	2	2
	2. <i>Neoscona vigilans</i>	1	1	1	1
	3. <i>Neoscona</i> sp.	4	4	4	4
Clubionidae	4. <i>Clubiona</i> sp.	3	3	3	2
Dictynidae	5. <i>Dictyna</i> sp.	2	1	2	1
Oxyopidae	6. <i>Oxyopes</i> sp.	1	1	1	2

Families	Species of predators	Number of			
		Species of aphid	Species of host plant	Triplets	Districts
Philodromidae	7. <i>Philodromus decoratus</i>	1	1	1	1
	8. <i>Philodromus</i> sp.	1	1	1	1
Tetragnathidae	9. <i>Tetragnatha javana</i>	1	1	1	1
Theridiidae	10. <i>Theridion</i> sp.	3	2	3	2
Thomisidae	11. <i>Indoxysticus minutus</i>	1	1	1	1
	12. <i>Misumenops khandalaensis</i>	1	1	1	1
	13. <i>Misumena</i> sp.	2	1	2	2
	14. <i>Ozyptila</i> sp.	1	1	1	1
	15. <i>Xysticus</i> sp.	2	2	2	2
Uloboridae	16. <i>Hyptiotes</i> sp.	1	1	1	1
Total		22	18	27	6

The detailed account of tri-trophic associations of spiders in Himachal Pradesh are given below.

a. Family: Araneidae

1. *Araneus* sp.

- *Capitophorus formosartemisiae* (Takahashi, 1921)
- *Artemisia* sp. - Kullu (Das & Raychaudhuri, 1983)
- *Cinara comata* Doncaster, 1956
- *Pinus* sp. - Shimla (Agarwala et al., 1981)

2. *Neoscona vigilans* (Blackwall, 1865)

- *Myzus dycei* Carver, 1961
- *Urtica parviflora* Roxb. - Solan (Das & Raychaudhuri, 1983)

3. *Neoscona* sp.

- *Chaitophorus kapuri* Hille Ris Lambers, 1966
- *Populus* sp. - Kullu (Das & Raychaudhuri, 1983)
- *Liosomaphis himalayensis* Basu, 1964
- *Berberis* sp. - Kullu (Das & Raychaudhuri, 1983)
- *Megoura dooarsis* (Ghosh & Raychaudhuri, 1969)
- *Indigofera heterantha* Wall. ex Brandis - Shimla (Das & Raychaudhuri, 1983)

- *Metopolophium* sp.

- *Spiraea canescens* D. Don - Kullu (Das & Raychaudhuri, 1983)

b. Family: Clubionidae

1. *Clubiona* spp.

- *Aphis gossypii* Glover, 1877
- *SZolanum melongena* L. - Kullu (Das & Raychaudhuri, 1983)
- *Macrosiphoniella sanborni* (Gillette, 1908)
- *Chrysanthemum* sp. - Solan (Das & Raychaudhuri, 1983)
- *Myzus ornatus* (Laing, 1932)
- *Capsicum annuum* L. - Kullu (Agarwala et al., 1981)

c. Family: Dictynidae

1. *Dictyna* sp.

- *Chaetosiphon tetrahodum* (Walker, 1849)
- *Rosa* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Sitobion rosaeiformis* (Das, 1918)
- *Rosa* sp. - Shimla (Agarwala et al., 1981)

d. Family: Oxyopidae

1. *Oxyopes* sp.

- *Aphis aurantii* Boyer de Fonsc., 1841
- *Camellia sinensis* (L.) Kuntze - Kangra, Mandi (Sharma & Kashyap, 2002)

e. Family: Philodromidae

1. *Philodromus decoratus* Tikader, 1962

- *Brevicoryne brassicae* (Linnaeus, 1758)
- *Raphanus sativus* L. - Shimla (Das & Raychaudhuri, 1983)

2. *Philodromus* sp.

- *Cinara* sp.
- *Pinus* sp. - Kullu (Agarwala et al., 1981)

f. Family: Tetragnathidae

1. *Tetragnatha javana* (Thorell, 1890)

- *Aphis spiraecola* Patch, 1914
- *Solanum nigrum* L. - Solan (Das & Raychaudhuri, 1983)

g. Family: Theridiidae

1. *Theridion* sp.

- *Aphis gossypii* Glover, 1877
 - *Zinnia* sp. - Solan (Agarwala et al., 1981)
- *Myzocallis pakistanica* (Hille Ris Lambers, 1966)
 - *Quercus* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Nippolachnus* sp.
 - *Quercus* sp. - Shimla (Das & Raychaudhuri, 1983)

h. Family: Thomisidae

1. *Indoxysticus minutus* (Tikader, 1960)

- *Myzus mumecola* (Matsumura, 1917)
 - *Prunus* sp. - Shimla (Das & Raychaudhuri, 1983)

2. *Misumenops khandalaensis* Tikader, 1965

- *Sitobion indicum* Basu, 1964
 - *Triticum aestivum* L. - Chamba (Das & Raychaudhuri, 1983)

3. *Misumena* sp.

- *Macrosiphum rosae* (Linnaeus, 1758)
 - *Rosa* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Sitobion rosaeiformis* (Das, 1918)
 - *Rosa* sp. - Kullu (Agarwala et al., 1981)

4. *Ozyptila* sp.

- *Myzus ornatus* (Laing, 1932)
 - *Capsicum annuum* L.- Chamba (Das & Raychaudhuri, 1983)

5. *Xysticus* sp.

- *Eutrichosiphum khasyanum* (Ghosh & Raychaudhuri, 1962)
 - *Quercus* sp. - Kangra (Das & Raychaudhuri, 1983)
- *Myzus ornatus* (Laing, 1932)
 - *Capsicum annuum* L. - Chamba (Das & Raychaudhuri, 1983)

i. Family: Uloboridae

1. *Hyptiotes* sp.

- *Sitobion rosaeiformis* (Das, 1918)

B. Class: Insecta

The aphidophagous predators in Himachal Pradesh belong to five orders of the class Insecta: Coleoptera, Dermaptera, Diptera, Hemiptera and Neuroptera.

1. Order: Coleoptera, Family: Coccinellidae (ladybird beetles)

Ladybird beetles (Coccinellidae) are highly efficient predatory insects and key natural enemies of agricultural pests. Both larvae and adults feed on soft-bodied insects such as aphids, whiteflies, scales, mealybugs, and mites (Dixon, 2000; Kumar & Omkar, 2023). They play a significant role in protecting crops including cereals, vegetables, fruits, and oilseeds (Singh & Singh, 2016). Their high predation efficiency, ecological adaptability, and widespread occurrence make them important agents in sustainable pest management and biological control programs (Obrycki & Kring, 1998; Kumar & Omkar, 2025). In India, Singh (2025b) catalogued 148 species of ladybirds associated with 181 aphid species feeding on 350 host plants, forming 3,102 tri-trophic associations.

In Himachal Pradesh, the family Coccinellidae comprised 39 species associated with 50 aphid species on 57 host plants, forming 218 distinct tri-trophic associations (Table 3), underscoring their pivotal role in aphid suppression and their established significance in natural and applied biological control.

Table 3. Number of species of aphidophagous Coccinellidae preying on different number of aphid species infesting different number of host plant species and triplets in Himachal Pradesh.

Species of predators	Number of			
	Species of aphid	Species of host plant	Triplets	Districts
1. <i>Adalia bipunctata</i>	1	3	3	1
2. <i>Adalia decempunctata</i>	1	1	1	1
3. <i>Adalia tetraspilota</i>	4	6	6	3
4. <i>Ballia</i> sp.	2	2	2	2
5. <i>Brumoides suturalis</i>	4	5	5	7
6. <i>Calvia punctata</i>	1	1	1	1
7. <i>Cheilomenes sexmaculata</i>	17	20	24	10
8. <i>Chilocorus infernalis</i>	2	2	2	2
9. <i>Coccinella luteopicta</i>	2	2	2	1
10. <i>Coccinella septempunctata</i>	27	30	43	10
11. <i>Coccinella transversalis</i>	9	10	13	8
12. <i>Coccinella undecimpunctata</i>	1	1	1	1
13. <i>Coelophora bissellata</i>	1	1	1	2
14. <i>Coelophora saucia</i>	1	1	1	2
15. <i>Cryptogonus</i> sp.	5	3	5	2
16. <i>Harmonia dimidiata</i>	7	7	9	6
17. <i>Harmonia eucharis</i>	1	1	1	1
18. <i>Harmonia</i> spp.	2	2	2	2
19. <i>Hippodamia tredecimpunctata</i>	1	3	3	1
20. <i>Hippodamia variegata</i>	19	20	27	8
21. <i>Illeis</i> sp.	1	3	3	1
22. <i>Megalocaria dilatata</i>	1	1	1	1
23. <i>Novius octoguttata</i>	1	1	1	1
24. <i>Oenopia billeti</i>	2	2	2	2

Species of predators	Number of			
	Species of aphid	Species of host plant	Triplets	Districts
25. <i>Oenopia kirbyi</i>	11	12	13	8
26. <i>Oenopia sauzeti</i>	16	15	19	6
27. <i>Oenopia sexareata</i>	7	7	7	2
28. <i>Oenopia</i> sp.	1	1	1	1
29. <i>Pharoscyrnus horni</i>	1	1	1	1
30. <i>Platynaspis saundersii</i>	3	3	3	1
31. <i>Priscibrunnus uropygialis</i>	4	4	4	3
32. <i>Propylea dissecta</i>	2	2	2	1
33. <i>Propylea luteopustulata</i>	3	3	3	2
34. <i>Rodolia octoguttata</i>	1	1	1	1
35. <i>Scymnus posticalis</i>	1	1	1	1
36. <i>Scymnus pyrocheilus</i>	1	1	1	1
37. <i>Scymnus</i> sp.	1	1	1	1
38. <i>Sticholotis marginalis</i>	1	1	1	1
39. <i>Verania</i> sp.	2	2	2	1
Total	50	55	218	10

Among the recorded species, *Coccinella septempunctata* exhibited the highest trophic versatility, attacking 27 aphid species across 30 host plants and contributing to 43 triplets, followed by *Hippodamia variegata* (19 aphid species, 20 host plants, 27 triplets), *Cheilomenes sexmaculata* (17 aphid species, 20 host plants, 24 triplets). Other species with notable diversity included *Oenopia sauzeti*, *Oenopia kirbyi*, and *Harmonia dimidiata*. Their wide prey range, strong ecological adaptability, and functional diversity highlight the crucial role of coccinellids in the natural regulation of aphid populations. As key components of agroecosystem stability, these beetles act as efficient biological control agents, supporting integrated pest management and significantly promoting sustainable agriculture in Himachal Pradesh.

The most frequently attacked aphid species were *Brachycaudus helichrysi* on almond and peaches and *Myzus persicae* on brassica vegetables and oilseeds and potato (each with 14 predator species), *Eriosoma lanigerum* on apple (13 predator species), *Brevicoryne brassicae* on brassica crops (11 predator species), and *Aphis pomi* on apple (10 predator species). Host plants showing the highest number of tri-trophic interactions included *Brassica oleracea* (36 triplets), *Malus domestica* (22 triplets), *Brassica juncea* (12 triplets), and *Prunus persica* (10 triplets).

The geographical distribution of tri-trophic associations across Himachal Pradesh exhibits a pronounced altitudinal gradient. The highest number of associations was recorded from Solan district (111 triplets), located within the mid-hill zone (~800–1,500 m a.s.l.), followed by Kangra district (47 triplets), representing predominantly lower to mid-hill subtropical elevations (~500–1,200 m a.s.l.), and Shimla district (44 triplets), situated in the higher mid-hill to sub-temperate zone (~1,500–2,200 m a.s.l.). In contrast, the high-altitude districts of Kinnaur and Lahaul & Spiti, characterised by cold desert conditions, support relatively lower diversity but include well-adapted, cold-tolerant species such as *Coccinella septempunctata* and *Hippodamia variegata*, underscoring ecological resilience under extreme environmental conditions. Kullu district exhibits moderate diversity, reflecting its transitional position between temperate and subtropical zones, while Chamba supports species adapted to aphid complexes associated with apple orchards and *Artemisia* vegetation. Conversely, districts such as Bilaspur, Hamirpur, and Mandi display comparatively limited diversity, dominated by widely distributed generalist predators including *Cheilomenes sexmaculata* and *Oenopia kirbyi*. Overall, the distribution of coccinellid predators across Himachal Pradesh

highlights considerable ecological plasticity, with mid-hill regions functioning as key centres of species richness and offering significant potential for natural biological control within diverse agroecosystems.

The detailed account of the tri-trophic associations of the ladybird in Himachal Pradesh is given below.

1. *Adalia bipunctata* (Linnaeus, 1758)

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)

2. *Adalia decempunctata* (Linnaeus, 1758)

- *Myzus persicae* (Sulzer, 1776)
 - *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)

3. *Adalia tetraspilota* (Hope, 1831)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Kotwal et al., 1984; Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Shimla (Singh, 1993)
- *Myzus persicae* (Sulzer, 1776)
 - *Solanum tuberosum* L. - Shimla (Trivedi & Rajagopal, 1988; Thakur & Chandla, 2013)

4. *Ballia* sp.

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Shimla (Verma & Chowdhuri, 1975)
- *Chaitophorus* sp.
 - *Populus* sp. - Kullu (Agarwala et al., 1981)

5. *Brumoides suturalis* (Fabricius, 1798)

- *Aphis affinis* del Guercio, 1911
 - *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
 - *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)

- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Sharma et al., 2009)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Brassica rapa* L. - Himachal Pradesh (Gautam, 1990)
- *Rhopalosiphum maidis* (Fitch, 1856)
 - *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021)

6. *Calvia punctata* (Mulsant, 1853)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991)

7. *Cheilomenes sexmaculata* (Fabricius, 1781)

- *Aphis affinis* del Guercio, 1911
 - *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
 - *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)
- *Aphis craccivora* Koch, 1854
 - *Trigonella foenum-graecum* L. - Solan (Poddar, 1982)
 - *Vicia faba* L. - Solan (Poddar, 1982)
- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Sharma et al., 2009)
- *Aphis longisetosa* Basu, 1970
 - *Abelmoschus esculentus* Moench - Solan, Kullu (Agarwala et al., 1981)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma & Verma, 1993)
- *Cavariella simlaensis* Chowdhuri, Basu & Raychaudhuri, 1969

- *Foeniculum vulgare* Mill. - Shimla (Das & Raychaudhuri, 1983)

- *Coloradoa rufomaculata* (Wilson, 1908)

- *Chrysanthemum* sp. - Solan (Das & Raychaudhuri, 1983)

- *Eriosoma lanigerum* (Hausmann, 1802)

- *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Shimla (Singh, 1993)

- *Hyadaphis coriandri* (Das, 1918)

- *Coriandrum sativum* L.- Solan (Das & Raychaudhuri, 1983)

- *Liosomaphis atra* Hille Ris Lambers, 1966

- *Berberis* sp. - Solan (Das & Raychaudhuri, 1983)

- *Lipaphis erysimi* (Kaltenbach, 1843)

- *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021)

- *Macrosiphum rosae* (Linnaeus, 1758)

- *Rosa* sp. - Shimla (Agarwala et al., 1981)

- *Myzus persicae* (Sulzer, 1776)

- *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021)

- *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)

- *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)

- *Pemphigus napaes* Buckton, 1896

- *Populus* sp. - Shimla (Agarwala et al., 1981)

- *Rhopalosiphum maidis* (Fitch, 1856)

- *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021); Solan (Sharma & Adlakha, 1981)

- *Sitobion rosaeiformis* (Das, 1918)

- *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)

8. *Chilocorus infernalis* (Mulsant, 1853)

- *Eriosoma lanigerum* (Hausmann, 1802)

- *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Solan (Rawat & Sangal, 1993; Sharma et al., 2015)

- *Lipaphis erysimi* (Kaltenbach, 1843)

- *Raphanus sativus* L. - Solan (Sharma et al., 2015)

9. *Coccinella luteopicta* (Mulsant, 1866)

- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Solan (Sharma et al., 2015)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Raphanus sativus* L. - Solan (Sharma et al., 2015)

10. *Coccinella septempunctata* Linnaeus, 1758

- *Aphis affinis* del Guercio, 1911
 - *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
 - *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)
- *Aphis aurantii* Boyer de Fonsc., 1841
 - *Camellia sinensis* (L.) Kuntze - Kangra, Mandi (Sharma & Kashyap, 2002)
- *Aphis craccivora* Koch, 1854
 - *Ipomoea batatas* (L.) Lam. - Solan (Poddar, 1982)
 - *Vicia faba* L. - Solan (Poddar, 1982)
- *Aphis fabae* Scopoli, 1763
 - *Rumex nepalensis* Spreng. - Solan (Agarwala et al., 1981)
 - *Solanum nigrum* L. - Solan (Sharma et al., 2009)
- *Aphis longisetosa* Basu, 1970
 - *Rubus ellipticus* Sm. - Solan (Das & Raychaudhuri, 1983)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Shimla (Verma & Chowdhuri, 1975)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Kullu (Thakur et al., 1989); Solan (Sharma & Verma, 1993; Sharma et al., 2020)
 - *Brassica oleracea* L. var. *capitata* - Kangra (Devi et al., 1996; Kharayat & Kumari, 2021); Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Kullu (Thakur et al., 1989; Kharayat & Kumari, 2021); Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma & Verma, 1993)
 - *Brassica rapa* L. - Kangra (Lakhanpal & Raj, 1998)

- *Capitophorus* sp.
 - *Rosa* sp. - Shimla (Agarwala et al., 1981)
- *Cavariella aegopodii* (Scopoli, 1763)
 - *Salix* sp. - Solan (Das & Raychaudhuri, 1983)
 - *Foeniculum vulgare* Mill. - Shimla (Das & Raychaudhuri, 1983)
- *Chaetosiphon gracilicorne* David et al., 1971
 - *Rosa* sp. - Solan (Das & Raychaudhuri, 1983)
- *Dysaphis emicis* (Mimeur, 1935)
 - *Malus domestica* (Suckow) Borkh. - Shimla (Agarwala et al., 1981)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Kangra (Gupta & Bhalla, 1993); Lahaul & Spiti (Vashisth et al., 2022); Shimla (Singh, 1993)
- *Hysteronura setariae* (Thomas, 1878)
 - *Saccharum officinarum* L. - Solan (Agarwala et al., 1981)
- *Liosomaphis atra* Hille Ris Lambers, 1966
 - *Valeriana jatamansi* Jones - Shimla (Das & Raychaudhuri, 1983)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021)
 - *Brassica rapa* L. - Kangra (Lakhanpal & Raj, 1998)
- *Matsumuraja capitophoroides* Hille Ris Lambers, 1966
 - *Rosa* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Myzus dycei* Carver, 1961
 - *Urtica* sp. - Solan (Das & Raychaudhuri, 1983)
- *Myzus mumecola* (Matsumura, 1917)
 - *Prunus armeniaca* L. - Shimla (Das & Raychaudhuri, 1983)
- *Myzus ornatus* (Laing, 1932)
 - *Salvia* sp. - Solan (Das & Raychaudhuri, 1983)
 - *Capsicum* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)

- *Brassica rapa* L. - Kangra (Lakhanpal & Raj, 1998)
- *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
- *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)
- *Nippolachnus* sp.
- *Quercus* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Rhopalosiphum maidis* (Fitch, 1856)
- *Triticum aestivum* L. - Kangra (Thakur et al., 2022)
- *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021); Solan (Sharma & Adlakha, 1981)
- *Rhopalosiphum padi* (Linnaeus, 1758)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion rosaeiformis* (Das, 1918)
- *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)
- *Rosa* sp. - Solan (Das & Raychaudhuri, 1983)
- *Tricaudatus polygoni* (Narzikulov, 1953)
- *Spiraea cantoniensis* Lour. - Solan (Das & Raychaudhuri, 1983)

11. *Coccinella transversalis* Fabricius, 1781

- *Aphis affinis* del Guercio, 1911
- *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
- *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)
- *Aphis pomi* de Geer, 1773
- *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Brachycaudus helichrysi* (Kaltenbach, 1843)
- *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)
- *Brevicoryne brassicae* (Linnaeus, 1758)
- *Brassica* sp. - Solan (Agarwala et al., 1981)
- *Macrosiphum rosae* (Linnaeus, 1758)
- *Rosa* sp. - Solan (Agarwala et al., 1981)
- *Myzus persicae* (Sulzer, 1776)

- *Capsicum* sp. - Solan (Sharma et al., 2015)
- *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)
- *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)
- *Raphanus sativus* L. - Shimla (Agarwala et al., 1981)
- *Rhopalosiphum maidis* (Fitch, 1856)
- *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021)
- *Rhopalosiphum padi* (Linnaeus, 1758)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

12. *Coccinella undecimpunctata* Linnaeus, 1758

- *Tuberolachnus salignus* (Gmelin, 1790)
- *Salix* spp. - Lahaul & Spiti (Kumar et al., 2025)

13. *Coelophora bissellata* Mulsant, 1850

- *Aphis pomi* de Geer, 1773
- *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)

14. *Coelophora saucia* (Mulsant, 1850)

- *Aphis pomi* de Geer, 1773
- *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; 2024)

15. *Cryptogonus* sp.

- *Aphis spiraeicola* Patch, 1914
- *Ipomea* sp. - Solan (Das & Raychaudhuri, 1983)
- *Capitophorus formosartemisiae* (Takahashi, 1921)
- *Artemisia* sp. - Chamba (Das & Raychaudhuri, 1983)
- *Impatiens impatiens* (Shinji, 1922)
- *Impatiens* sp. - Chamba (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
- *Ipomea* sp. - Solan (Das & Raychaudhuri, 1983)
- *Pleotrichophorus glandulosus* (Kaltenbach, 1846)
- *Artemisia* sp. - Chamba (Das & Raychaudhuri, 1983)

16. *Harmonia dimidiata* (Fabricius, 1781)

- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Kullu (Thakur et al., 1989); Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Kullu (Thakur et al., 1989)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus sylvestris* (L.) Mill. - Chamba (Singh C et al., 2024)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
- *Myzus ornatus* (Laing, 1932)
 - *Salvia* sp. - Solan (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
- *Rhopalosiphum maidis* (Fitch, 1856)
 - *Zea mays* L. - Solan (Sharma & Adlakha, 1981)

17. *Harmonia eucharis* (Mulsant, 1853)

- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Kangra (Gupta & Bhalla, 1993)

18. *Harmonia* sp.

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Shimla (Verma & Chowdhuri, 1975)
- *Chaitophorus* sp.
 - *Populus* sp. - Kullu (Agarwala et al., 1981)

19. *Hippodamia tredecimpunctata* (Linnaeus, 1758)

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)

20. *Hippodamia variegata* (Goeze, 1777)

- *Aphis craccivora* Koch, 1854
 - *Vicia faba* L. - Solan (Poddar, 1982)
- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Sharma et al., 2009)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Aphis spiraeicola* Patch, 1914
 - *Rumex nepalensis* Spreng. - Shimla (Das & Raychaudhuri, 1983)
 - *Citrus* sp.- Mandi, Solan (Das & Raychaudhuri, 1983)
- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Kullu (Thakur et al., 1989); Solan (Sharma & Verma, 1993; Sharma et al., 2020)
 - *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Kullu (Thakur et al., 1989); Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma & Verma, 1993)
 - *Brassica* sp. - Solan (Das & Raychaudhuri, 1983)
 - *Raphanus sativus* L. - Shimla (Das & Raychaudhuri, 1983)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Lahaul & Spiti (Vashisth et al., 2022); Shimla (Kumar, 2017)
- *Hyperomyzus carduellinus* (Theobald, 1915)
 - *Sonchus* sp. - Solan (Das & Raychaudhuri, 1983)
- *Liosomaphis himalayensis* Basu, 1964
 - *Berberis* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
- *Macrosiphum rosae* (Linnaeus, 1758)

- *Rosa* sp. - Solan (Das & Raychaudhuri, 1983)
- *Myzus ornatus* (Laing, 1932)
 - *Salvia* sp. - Solan (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)
- *Rhopalosiphum maidis* (Fitch, 1856)
 - *Zea mays* L. - Solan (Sharma & Adlakha, 1981)
- *Rhopalosiphum padi* (Linnaeus, 1758)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
 - *Cymbopogon nardus* (L.) Rendle - Kangra (Dixit et al., 2019)
- *Sitobion miscanthi* (Takahashi, 1921)
 - *Triticum aestivum* L. - Kullu (Hameed et al., 1975)
- *Sitobion rosaeiformis* (Das, 1918)
 - *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)
- *Uroleucon sonchi* (Linnaeus, 1767)
 - *Sonchus* sp. - Solan (Das & Raychaudhuri, 1983)

21. *Illeis* spp.

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)

22. *Megalocaria dilatata* (Fabricius, 1775)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)

23. *Novius octoguttata* (Weise, 1892)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)

24. *Oenopia billieti* (Mulsant, 1853)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)

- *Prunus persica* (L.) Stokes - Shimla (Verma & Chowdhuri, 1975)

- Unidentified aphid

- *Spiraea* sp. - Chamba (Poorani, 2002)

25. *Oenopia kirbyi* Mulsant, 1850

- *Aphis gossypii* Glover, 1877

- *Cucumis sativus* L. - Solan (Kumari et al., 2021a); Shimla, Mandi (Kumari et al., 2021b)

- *Aphis paraverbasci* Chakrabarti, 1976

- *Verbascum* sp. - Kangra (Das & Raychaudhuri, 1983)

- *Aphis spiraeicola* Patch, 1914

- *Solanum nigrum* L. - Kangra (Das & Raychaudhuri, 1983)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)

- *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)

- *Brevicoryne brassicae* (Linnaeus, 1758)

- *Brassica oleracea* L. var. *botrytis* - Solan (Sharma & Verma, 1993)

- *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)

- *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)

- *Coloradoa rufomaculata* (Wilson, 1908)

- *Chrysanthemum* sp. - Solan (Agarwala et al., 1981)

- *Eriosoma lanigerum* (Hausmann, 1802)

- *Malus domestica* (Suckow) Borkh. - Solan (Sharma et al., 2015)

- *Macrosiphum rosae* (Linnaeus, 1758)

- *Rosa* sp. - Solan (Gaikwad et al., 2022)

- *Myzus persicae* (Sulzer, 1776)

- *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)

- *Rhopalosiphum maidis* (Fitch, 1856)

- *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021)

- *Sitobion rosaeiformis* (Das, 1918)

- *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)

26. *Oenopia sauzeti* Mulsant, 1866

- *Aphis gossypii* Glover, 1877

- *Rumex nepalensis* Spreng. - Shimla (Agarwala et al., 1981)

- *Aphis kurosawai* Takahashi, 1921
 - *Artemisia* sp. - Chamba (Das & Raychaudhuri, 1983)
- *Aphis longisetosa* Basu, 1970
 - *Rubus* sp. - Kullu (Agarwala et al., 1981)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Shimla (Singh, 1993)
- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991); Solan (Chauhan et al., 2024)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma & Verma, 1993; Sharma et al., 2020)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Verma, 1993)
 - *Brassica oleracea* L. var. *gongylodes* - Solan (Sharma & Verma, 1993)
- *Capitophorus formosartemisiae* (Takahashi, 1921)
 - *Artemisia* sp. - Chamba (Das & Raychaudhuri, 1983)
- *Cavariella aegopodii* (Scopoli, 1763)
 - *Rubus ellipticus* Sm. - Kullu (Das & Raychaudhuri, 1983)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Solan (Sharma et al., 2015)
- *Liosomaphis atra* Hille Ris Lambers, 1966
 - *Berberis* sp. - Solan (Das & Raychaudhuri, 1983)
- *Macrosiphum euphorbiae* (Thomas, 1878)
 - *Solanum tuberosum* L. - Solan (Sharma et al., 2025)
- *Macrosiphum rosae* (Linnaeus, 1758)
 - *Rosa* sp. - Solan (Agarwala et al., 1981)
- *Melanaphis donacis* (Passerini, 1862)
 - *Arundo donax* L. - Chamba (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)

- *Prunus armeniaca* L. - Solan (Agarwala et al., 1981)

- *Phorodon cannabis* Passerini, 1860

- *Cannabis sativa* L. - Kullu (Agarwala et al., 1981)

27. *Oenopia sexareata* (Mulsant, 1853)

- *Brachycaudus helichrysi* (Kaltenbach, 1843)

- *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)

- *Eriosoma lanigerum* (Hausmann, 1802)

- *Malus domestica* (Suckow) Borkh. - Solan (Sharma et al., 2015)

- *Indoidiopterus geranii* (Chowdhuri et al., 1969)

- *Geranium wallichianum* D. Don - Solan (Das & Raychaudhuri, 1983)

- *Pemphigus napaecus* Buckton, 1896

- *Populus* sp. - Shimla (Agarwala et al., 1981)

- *Sitobion miscanthi* (Takahashi, 1921)

- *Triticum aestivum* L. - Solan (Das & Raychaudhuri, 1983)

- *Sitobion rosaeiformis* (Das, 1918)

- *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)

- *Rhopalosiphum maidis* (Fitch, 1856)

- *Zea mays* L. - Solan (Sharma & Adlakha, 1981)

28. *Oenopia* sp.

- *Aphis fabae* Scopoli, 1763

- *Solanum nigrum* L. - Solan (Sharma et al., 2009)

29. *Pharoscymnus horni* (Weise, 1900)

- *Myzus persicae* (Sulzer, 1776)

- *Brassica oleracea* L. var. *botrytis* - Solan (Singh C et al., 2025)

30. *Platynaspis saundersii* Crotch, 1874

- *Aphis craccivora* Koch, 1854

- *Solanum nigrum* L. - Solan (Kasi & Waiba, 2023)

- *Aphis pomi* De Geer, 1773

- *Malus domestica* (Suckow) Borkh - Solan (Sharma et al., 2017)

- *Myzus persicae* (Sulzer, 1776)

- *Brassica oleracea* L. var. *botrytis* - Solan (Singh C et al., 2025)

31. *Priscibrumus uropygialis* (Mulsant, 1853)

- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Solan (Sharma et al., 2015)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Raphanus sativus* L. - Solan (Sharma et al., 2015)
- *Myzus ornatus* (Laing, 1932)
 - *Ajuga parviflora* Benth. - Shimla (Das & Raychaudhuri, 1983)

32. *Propylea dissecta* (Mulsant, 1850)

- *Aphis affinis* del Guercio, 1911
 - *Mentha arvensis* L. - Kangra (Singh & Bali, 1993)
- *Myzus persicae* (Sulzer, 1776)
 - *Hyoscyamus muticus* L. - Kangra (Singh & Bali, 1993)

33. *Propylea luteopustulata* (Mulsant, 1850)

- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Raphanus sativus* L. - Solan (Sharma et al., 2015)
- *Myzus persicae* (Sulzer, 1776)
 - *Zinnia elegans* L. - Shimla (Das & Raychaudhuri, 1983)
- *Rhopalosiphum maidis* (Fitch, 1856)
 - *Zea mays* L. - Solan (Sharma & Adlakha, 1981)

34. *Rodolia octoguttata* Weise, 1910

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
 - *Prunus persica* (L.) Stokes - Solan (Sharma et al., 2015)

35. *Scymnus posticalis* Sicard, 1913

- *Myzus persicae* (Sulzer, 1776)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Singh C et al., 2025)

36. *Scymnus pyrocheilus* Mulsant, 1853

- *Capitophorus formosartemisiae* (Takahashi, 1921)
 - *Artemisia* sp. - Chamba (Das & Raychaudhuri, 1983)

37. *Scymnus* sp.

- *Cavariella aegopodii* (Scopoli, 1763)
- *Salix* sp. - Solan (Das & Raychaudhuri, 1983)

38. *Sticholotis marginalis* Kapur, 1956

- *Aphis fabae* Scopoli, 1763
- *Solanum nigrum* L. - Solan (Sharma et al., 2009)

39. *Verania* sp.

- *Macrosiphum rosae* (Linnaeus, 1758)
- *Rosa* sp. - Shimla (Agarwala et al., 1981)
- *Myzaphis rosarum* (Kaltenbach, 1843)
- *Rosa* sp. - Shimla (Agarwala et al., 1981)

2. Order: Dermaptera, Family: Forficulidae (Earwigs)

Members of earwig are omnivorous insects that feed on plant material, other insects, and soft-bodied arthropods such as aphids. In Himachal Pradesh, only a single species, *Forficula auricularia* Linnaeus, 1758 was observed preying on *Eriosoma lanigerum* in Kullu valley infesting European crab apple, *Malus sylvestris* (Thakur et al., 1988). In India, it was also reported from Uttarakhand, Odisha, and Telangana feeding on many aphid species on different host plants (Singh & Srivastav, 2025).

3. Order: Diptera, Family: Syrphidae (hover flies, flower flies)

The hover flies represents the sole aphidophagous Diptera recorded from Himachal Pradesh which play a dual ecological role, acting as key pollinators and as natural enemies of aphids through their predatory larvae. This dual functionality enhances crop productivity and supports sustainable pest management by minimising reliance on chemical insecticides (Li et al., 2023). Nationally, 49 aphidophagous syrphid species from 17 genera have been documented in India, preying on 94 aphid species associated with 149 host plants, resulting in 1,025 documented predator-aphid-host plant tri-trophic linkages across 26 states and union territories (Singh, 2026c).

The family exhibits extensive tri-trophic associations in Himachal Pradesh, linking 21 aphidophagous species with a diverse array of aphid prey (33 species) and host plants (37 species) across 10 districts of multiple ecological zones, forming 110 tri-trophic associations (Table 4). These associations extend from low hill regions (Solan, Kangra, Mandi) to high-altitude localities (Kinnaur, Lahaul & Spiti, Chamba), reflecting the ecological adaptability and functional importance of syrphids in regulating aphid populations.

Among the recorded taxa, *Episyrphus balteatus* emerged as the most polyphagous and widely distributed (8 districts) species, preying on 20 aphid species infesting on 16 host plants, including *Brevicoryne brassicae* on brassica crops, *Myzus persicae* on brassica crops and brinjal, *Eriosoma lanigerum* on apple, and *Rhopalosiphum maidis* on wheat and maize. *Eupeodes confrater* and *Ischiodon scutellaris* followed, with 13 and 12 tri-trophic associations, respectively, indicating their broad prey adaptability in multiple cropping systems with broad altitudinal distribution, particularly in Solan, Shimla, Kinnaur, and Kullu, while *Betasyrphus serarius*, *Eupeodes corollae*, and *Melanostoma* spp. displayed generalist feeding

habits across cereals, crucifers, and fruit crops. Other hover flies, such as *Scaeva pyrastris*, *Scaeva selenitica*, *Sphaerophoria indiana*, and *Syrphus vitripennis*, were more locally distributed but played notable roles in controlling key aphid pests like *Brevicoryne brassicae* and *Myzus persicae*.

Table 4. Number of species of aphidophagous Coccinellidae preying on different number of aphid species infesting different number of host plant species and triplets in Himachal Pradesh.

Species of predators	Number of			
	Species of aphid	Species of host plant	Triplets	Districts
1. <i>Betasyrphus serarius</i>	9	9	9	5
2. <i>Episyrphus balteatus</i>	20	16	26	8
3. <i>Episyrphus viridaureus</i>	3	2	3	2
4. <i>Eupeodes bucculatus</i>	1	1	1	1
5. <i>Eupeodes confrater</i>	11	8	13	5
6. <i>Eupeodes corollae</i>	5	7	8	5
7. <i>Eupeodes frequens</i>	3	4	4	1
8. <i>Eupeodes</i> spp.	3	2	4	2
9. <i>Ischiodon scutellaris</i>	9	9	12	5
10. <i>Melanostoma orientale</i>	3	5	5	3
11. <i>Melanostoma univittatum</i>	1	1	1	1
12. <i>Melanostoma</i> sp.	3	2	3	6
13. <i>Paragus rufocinctus</i>	2	2	2	2
14. <i>Scaeva latimaculata</i>	1	1	1	1
15. <i>Scaeva pyrastris</i>	3	5	8	2
16. <i>Scaeva selenitica</i>	1	1	1	1
17. <i>Sphaerophoria indiana</i>	2	1	2	1
18. <i>Sphaerophoria</i> sp.	2	1	2	1
19. <i>Syrphus vitripennis</i>	1	1	1	1
20. <i>Syrphus</i> sp.	2	2	2	2
21. <i>Xanthogramma</i> sp.	2	2	2	1
Total	33	37	110	10

Among the ten districts analysed, Solan recorded the highest number of tri-trophic associations (57), followed by Shimla (23), Kangra (22), Kullu (18), and Chamba (16). Collectively, these districts represent the principal hotspots of syrphid-aphid-plant interactions within the state. In contrast, the high-altitude districts of Kinnaur and Lahaul and Spiti, each with 12 recorded associations, exhibited comparatively lower but still notable levels of tri-trophic interactions, likely constrained by harsher climatic conditions and shorter growing seasons. Moderate to low levels of association were observed in Mandi (5), and in Bilaspur and Hamirpur (one association each), indicating more localised predator-prey networks. These interactions are primarily associated with specific cropping systems, particularly apple orchards, brassica crops, and cereals.

The detailed accounts of tri-trophic associations of the hover flies in Himachal Pradesh are mentioned below.

1. *Betasyrphus serarius* (Wiedemann, 1830)

- *Aphis fabae* Scopoli, 1763

- *Solanum nigrum* L - Solan (Verma et al., 2005)

- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Aphis verbasci* Schrank, 1801
 - *Verbascum thapsus* L. - Solan (Das & Raychaudhuri, 1983)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987)
- *Doraphis populi* (Maskell, 1898)
 - *Populus* sp. - Kullu (Das & Raychaudhuri, 1983)
- *Myzackaia verbasci* (Chawdhuri et al., 1969)
 - *Rubia cordifolia* L. - Kangra (Das & Raychaudhuri, 1983)
- *Myzus dycei* Carver, 1961
 - *Urtica* sp. - Shimla (Das & Raychaudhuri, 1983)
- *Myzus persicae* (Sulzer, 1776)
 - *Prunus persica* (L.) Batsch - Himachal Pradesh (Rao, 1969)
- *Sitobion rosaeformis* (Das, 1918)
 - *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)

2. *Episyrphus balteatus* (De Geer, 1776)

- *Aphis craccivora* Koch, 1854
 - *Solanum melongena* L. - Solan (Poddar, 1982)
- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Verma et al., 2005)
- *Aphis gossypii* Glover, 1877
 - *Solanum melongena* L. - Solan (Vishwajeet, 2020)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006)
- *Brachycaudus cardui* (Linnaeus, 1758)
 - *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Brachycaudus* sp.
 - *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Brevicoryne brassicae* (Linnaeus, 1758)

- *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021); Solan (Singh et al., 2020)
- *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Verma & Makhmoor, 1987; Sharma & Bhalla, 1988)
- *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Capitophorus carduinus* (Walker, 1850)
- *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Dyaphis foeniculus* (Theobald, 1923)
- *Foeniculum vulgare* Mill. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Eriosoma lanigerum* (Hausmann, 1802)
- *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Shimla (Verma & Singh, 1985)
- *Indiodiopterus geranii* (Chowdhuri et al., 1969)
- *Geranium* sp. - Solan (Das & Raychaudhuri, 1983)
- *Lipaphis erysimi* (Kaltenbach, 1843)
- *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021)
- *Macrosiphoniella sanborni* (Gillette, 1908)
- *Chrysanthemum* sp. - Shimla (Agarwala et al., 1981)
- *Mindarus japonicus* Takahashi, 1931
- *Abies* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Myzus ornatus* (Laing, 1932)
- *Ajuga* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Myzus persicae* (Sulzer, 1776)
- *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
- *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)
- *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Bhalla, 1991)
- *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)
- *Rhopalosiphum padi* (Linnaeus, 1758)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

- *Sitobion miscanthi* (Takahashi, 1921)
 - *Triticum aestivum* L. - Solan (Das & Raychaudhuri, 1983)
- *Sitobion rosaeiformis* (Das, 1918)
 - *Rosa bourboniana* L. - Shimla (Kakar, 2006); Solan (Kakar & Sood, 1989)

3. *Episyrphus viridaureus* (Wiedemann, 1824)

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Kotwal et al., 1984)
- *Rhopalosiphum padi* (Linnaeus, 1758)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

4. *Eupeodes bucculatus* Rondani, 1857

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987)

5. *Eupeodes confrater* (Wiedemann, 1830)

- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Sood et al., 2007)
- *Aphis pomi* de Geer, 1773
 - *Malus domestica* (Suckow) Borkh. - Shimla, Mandi (Kumari et al., 2006; Kumari, 2019)
- *Brachycaudus cardui* (Linnaeus, 1758)
 - *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Brachycaudus* sp.
 - *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987; Sharma et al., 2020)
- *Capitophorus carduinus* (Walker, 1850)
 - *Cirsium* sp. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Dysaphis* sp.
 - *Malus domestica* (Suckow) Borkh. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)

- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus domestica* (Suckow) Borkh. - Shimla (Singh, 1993)
 - *Malus sylvestris* (L.) Mill. - Chamba (Singh C et al., 2024); Kullu (Thakur & Pawar, 1986)
- *Myzus ornatus* (Laing, 1932)
 - *Capsicum annuum* L. - Chamba, Kullu, Shimla, Solan (Siddiqui & Krishnaswamy, 1972)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Bhalla, 1991)
- *Uroleucon simlaense* Chakrabarti, Ghosh & Raychaudhuri, 1971
 - *Artemisia* sp. - Solan (Das & Raychaudhuri, 1983)

6. *Eupeodes corollae* (Fabricius, 1794)

- *Aphis craccivora* Koch, 1854
 - *Vicia faba* L. - Solan (Poddar, 1982)
- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Verma et al., 2005)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Makhmoor & Verma, 1987; Sharma & Bhalla, 1988)
 - *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Palial et al., 2023)
 - *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
 - *Raphanus sativus* L. - Kullu (Agarwala et al., 1981)
- *Eriosoma lanigerum* (Hausmann, 1802)
 - *Malus sylvestris* (L.) Mill. - Chamba (Singh C et al., 2024)
- *Myzus persicae* (Sulzer, 1776)
 - *Raphanus sativus* L. - Kullu (Agarwala et al., 1981)

7. *Eupeodes frequens* (Matsumura, 1917)

- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Verma et al., 2005; Sood et al., 2007)
- *Brevicoryne brassicae* (Linnaeus, 1758)

- *Brassica juncea* (L.) Czern. - Solan (Singh et al., 2020)
- *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Bhalla, 1991; Sharma et al., 2020)
- *Myzus persicae* (Sulzer, 1776)
- *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)

8. *Eupeodes* spp.

- *Brevicoryne brassicae* (Linnaeus, 1758)
- *Brassica napus* L. - Kangra (Lakhanpal & Raj, 1998)
- *Lipaphis erysimi* (Kaltenbach, 1843)
- *Brassica napus* L. - Kangra (Lakhanpal & Raj, 1998)
- *Myzus persicae* (Sulzer, 1776)
- *Brassica napus* L. - Kangra (Lakhanpal & Raj, 1998)
- *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)

9. *Ischiodon scutellaris* (Fabricius, 1805)

- *Acyrtosiphon rubi* (Narzikulov, 1957)
- *Rubus ellipticus* Sm. - Solan (Das & Raychaudhuri, 1983)
- *Aphis gossypii* Glover, 1877
- *Solanum melongena* - Solan (Vishwajeet, 2020)
- *Aphis punicae* Passerini, 1863
- *Punica granatum* L. - Solan (Das & Raychaudhuri, 1983)
- *Aphis verbasci* Schrank, 1801
- *Verbascum* sp. - Kullu (Agarwala et al., 1981)
- *Brevicoryne brassicae* (Linnaeus, 1758)
- *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)
- *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Verma & Makhmoor, 1987; Palial et al., 2025)
- *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Lipaphis erysimi* (Kaltenbach, 1843)
- *Brassica juncea* (L.) Czern - Kangra (Soni et al., 2021)
- *Myzus persicae* (Sulzer, 1776)
- *Brassica juncea* (L.) Czern. - Kangra (Soni et al., 2021)

- *Rhopalosiphum padi* (Linnaeus, 1758)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

10. *Melanostoma orientale* (Wiedemann, 1824)

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
 - *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
 - *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Lipaphis erysimi* (Kaltenbach, 1843)
 - *Sinapis* sp. - Solan (Rao, 1969)
- *Sitobion rosaeiformis* (Das, 1918)
 - *Rosa* sp. - Solan (Agarwala et al., 1981)

11. *Melanostoma univittatum* (Wiedemann, 1824)

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987)

12. *Melanostoma* sp.

- *Rhopalosiphum maidis* (Fitch, 1856)
 - *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021)
- *Rhopalosiphum padi* (Linnaeus, 1758)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

13. *Paragus rufocinctus* (Brunetti, 1908) [misident. *Paragus tibialis* (Fallén, 1817)]

- *Brachycaudus rumexicolens* (Patch, 1917)
 - *Rumex* sp. - Kullu (Das & Raychaudhuri, 1983)
- *Metopolophium* sp.
 - *Stephania hernandiifolia* Walp. - Chamba (Das & Raychaudhuri, 1983)

14. *Scaeva latimaculata* (Brunetti, 1923)

- *Hyperomyzus carduellinus* (Theobald, 1915)
 - *Emilia sonchifolia* L. (DC.) - Himachal Pradesh (Agarwala et al., 1984)

15. *Scaeva pyrastris* (Linnaeus, 1758)

- *Aphis fabae* Scopoli, 1763
 - *Solanum nigrum* L. - Solan (Sood et al., 2007)
- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987; Palial et al., 2022)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Bhalla, 1988)
 - *Raphanus sativus* L. - Himachal Pradesh (Agarwala et al., 1984)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)
 - *Brassica oleracea* L. var. *capitata* - Solan (Sharma & Bhalla, 1991)
 - *Raphanus sativus* L. - Himachal Pradesh (Agarwala et al., 1984)
 - *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)

16. *Scaeva selenitica* (Meigen, 1822)

- *Acyrtosiphon rubi* Narzikulov, 1957
 - *Rubus ellipticus* Sm. - Solan (Das & Raychaudhuri, 1983)

17. *Sphaerophoria indiana* Bigot, 1884

- *Brevicoryne brassicae* (Linnaeus, 1758)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Verma & Makhmoor, 1987; Palial et al., 2025)
- *Myzus persicae* (Sulzer, 1776)
 - *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)

18. *Sphaerophoria* sp.

- *Rhopalosiphum padi* (Linnaeus, 1758)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)
- *Sitobion avenae* (Fabricius, 1775)
 - *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

19. *Syrphus vitripennis* Meigen, 1822

- *Myzus dycei* Carver, 1961
 - *Urtica* sp. - Shimla (Das & Raychaudhuri, 1983)

20. *Syrphus* sp.

- *Aphis aurantii* Boyer de Fonsc., 1841

- *Camellia sinensis* (L.) Kuntze - Kangra, Mandi (Sharma & Kashyap, 2002)

• *Myzus dycei* Carver, 1961

- *Urtica* sp. - Himachal Pradesh (Agarwala et al., 1984)

21. *Xanthogramma* sp.

• *Acyrtosiphon rubi* Narzikulov, 1957

- *Rubus ellipticus* Sm. - Solan (Das & Raychaudhuri, 1983)

• *Hyperomyzus carduellinus* (Theobald, 1915)

- *Emilia sonchifolia* L. (DC.) - Solan (Agarwala et al., 1981)

4. Order: Hemiptera, Family: Anthocoridae

1. *Anthocoris confusus* Reuter, 1884

• *Brachycaudus helichrysi* (Kaltenbach, 1843)

- *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991)

5. Order: Neuroptera (lacewings)

The order Neuroptera is cosmopolitan and largely predatory, with many species feeding on soft-bodied insects such as aphids. In India, aphidophagy is recorded in four families, Chrysopidae, Coniopterygidae, Dilaridae, and Hemerobiidae (Singh *et al.*, 2024b). Chrysopidae (larvae) and Hemerobiidae (larvae and adults) are key biological control agents in agroecosystems (Devetak & Klokočovník, 2016), though comparatively less studied than syrphids and coccinellids (Bakthavatsalam & Varshney, 2023). Overall, 32 aphidophagous lacewing species are known to prey on 68 aphid species (37 genera) associated with 107 host plants across 23 states and union territories of India (Singh *et al.*, 2024b).

Table 5 shows that seven lacewing species preyed on 11 aphid species across 14 host plants, forming 21 distinct tri-trophic associations. Despite low species richness, lacewings were widely distributed across ten districts of Himachal Pradesh, indicating considerable ecological adaptability and significance as aphid predators across diverse agroclimatic zones.

Among the three recorded families (Chrysopidae, Coniopterygidae, and Hemerobiidae), Chrysopidae was dominant and present in all districts, whereas Coniopterygidae and Hemerobiidae exhibited more restricted distributions. *Chrysoperla zastrowi silleni* was the most widespread species, occurring in all ten districts and preying on five aphid species associated with multiple host plants, including *Brassica oleracea*, *Malus domestica*, *Solanum tuberosum*, *Capsicum* spp., and *Zea mays*. Other species showed comparatively limited distributions. Districts such as Solan, Kullu, Kangra, and Kinnaur emerged as key centres of lacewing-aphid-plant interactions, while Bilaspur, Hamirpur, and Mandi recorded fewer associations, likely reflecting limited sampling. Overall, the pattern underscores the broad ecological amplitude of *Chrysoperla zastrowi silleni* and highlights the importance of lacewings as effective aphid biocontrol agents across the state.

Table 5. Number of species of aphidophagous lacewings preying on different numbers of aphid species infesting different numbers of host plant species and triplets in Himachal Pradesh.

Species of predators		Number of			
		Species of aphid	Species of host plant	Triplets	Districts
Chrysopidae	<i>Brinckochrysa scelestes</i>	1	1	1	1
	<i>Chrysopa pallens</i>	3	3	3	3
	<i>Chrysopa</i> sp.	3	3	3	3
	<i>Chrysoperla zastrowi sillemi</i>	5	8	10	10
	<i>Mallada desjardinsi</i>	1	1	1	1
Coniopterygidae	<i>Coniocompsa indica</i>	1	1	1	1
Hemerobiidae	<i>Micromus</i> sp.	2	1	2	2
Total		11	13	21	10

a. Family: Chrysopidae

1. *Brinckochrysa scelestes* (Banks, 1911)

- *Eriosoma lanigerum* (Hausmann, 1802)
- *Malus sylvestris* (L.) Mill. - Kullu (Thakur et al., 1988)

2. *Chrysopa pallens* (Rambur, 1838)

- *Aphis craccivora* Koch, 1854
- *Vicia faba* L. - Solan (Poddar, 1982)
- *Aphis gossypii* Glover, 1877
- *Solanum melongena* L. - Kangra (Das & Raychaudhuri, 1983)
- *Myzus ornatus* (Laing, 1932)
- *Capsicum* sp. - Chamba (Das & Raychaudhuri, 1983)

3. *Chrysopa* sp.

- *Brachycaudus helichrysi* (Kaltenbach, 1843)
- *Prunus amygdalus* Batsch - Kinnaur (Bhardwaj, 1991)
- *Eriosoma lanigerum* (Hausmann, 1802)
- *Malus sylvestris* (L.) Mill. - Kullu (Thakur & Pawar, 1986)
- *Sitobion rosaeiformis* (Das, 1918)

- *Rosa bourboniana* L. - Solan (Kakar & Sood, 1989)

4. *Chrysoperla zastrowi sillemi* (Esben- Petersen, 1935)

- *Aphis gossypii* Glover, 1877
- *Cucumis sativus* L. - Solan (Kumari et al., 2020)
- *Brevicoryne brassicae* (Linnaeus, 1758)
- *Brassica oleracea* L. var. *botrytis* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma et al., 2020; Chandana et al., 2023)
- *Brassica oleracea* L. var. *capitata* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024); Solan (Sharma et al., 2020; Chandana et al., 2023)
- *Brassica oleracea* L. var. *gongylodes* - Kinnaur, Lahaul & Spiti (Semwal et al., 2024)
- *Eriosoma lanigerum* (Hausmann, 1802)
- *Malus domestica* (Suckow) Borkh. - Chamba (Singh C et al., 2024); Kullu (Thakur et al., 1988); Lahaul & Spiti (Vashisth et al., 2022); Shimla (Singh, 1993)
- *Malus domestica* (Suckow) Borkh. -
- *Myzus persicae* (Sulzer, 1776)
- *Solanum tuberosum* L. - Shimla (Thakur & Chandla, 2013)
- *Brassica oleracea* L. var. *botrytis* - Solan (Sharma et al., 2020)
- *Capsicum* sp. - Solan (Bhat et al., 2024)
- *Rhopalosiphum maidis* (Fitch, 1856)
- *Zea mays* L. - Bilaspur, Chamba, Hamirpur, Mandi, Kangra, Kullu (Ankita et al., 2021)

5. *Mallada desjardinsi* (Navás, 1911)

- *Aphis gossypii* Glover, 1877
- *Cucumis sativus* L. - Solan (Kumari et al., 2021b)

b. Family: Coniopterygidae

1. *Coniocompsa indica* Withycombe, 1925

- *Eriosoma lanigerum* (Hausmann, 1802)
- *Malus domestica* (Suckow) Borkh. - Kullu (Rahman, 1940)

c. Family: Hemerobiidae

1. *Micromus* sp.

- *Rhopalosiphum padi* (Linnaeus, 1758)

- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

- *Sitobion avenae* (Fabricius, 1775)

- *Triticum aestivum* L. - Kangra (Dixit et al., 2019)

Conclusion

The present checklist demonstrates that Himachal Pradesh supports a rich and functionally diverse assemblage of aphidophagous predators structured through complex tri-trophic interactions across varied agroecological zones. With 85 predator species linked to 73 aphids on 75 host plants, the dominance of Coccinellidae and Syrphidae underscores their central role in natural aphid regulation, while spiders, lacewings, and other minor guilds contribute to trophic stability and resilience. Spatial patterns highlight mid-hill districts, particularly Solan, as biodiversity hotspots, though even high-altitude regions sustain ecologically significant predator communities. Overall, this comprehensive baseline enhances understanding of predator diversity, prey specificity, and host-plant linkages, and provides a strong foundation for biodiversity conservation and the development of region-specific, ecologically sustainable Integrated Pest Management strategies in Himachal Pradesh.

Acknowledgements

I would like to thank the reviewers for their valuable comments and suggestions to improve the paper quality.

Conflict of interest

The authors declare that they have no competing interests.

References

- Agarwala, B.K., Ghosh, D., Das, S.K., Poddar, S.C. & Raychaudhuri, D.N. 1981. Parasites and predators of aphids (Homoptera: Aphididae) from India. V. New records of two aphidiid parasites, nine arachnids and one dipteran predator from India. *Entomon*, 6(3), 233-238.
- Agarwala, B.K., Laska, P. & Raychaudhuri, D.N. (1984). Prey records of aphidophagous syrphid flies from India (Diptera: Syrphidae). *Acta Entomologica Bohemoslovaca*, 81, 15-21.
- Andersen, A.N. (1999). My bioindicator or yours? Making the selection. *Journal of Insect Conservation*, 3, 1-4.
- Ankita, Sharma, P.K. & Mehta, V. (2021). Natural enemies associated with insect pests of maize in sub-tropical and sub-humid zones of Himachal Pradesh, India. *Journal of Experimental Zoology, India*, 24(1), 329-335.
- Bakthavatsalam, N. & Varshney, R. (2023). Chrysopids (Neuroptera: Chrysopidae). In: *Insect Predators in Pest Management* (Ed. Omkar), CRC Press, Taylor & Francis Group, LLC, pp. 161–174. doi: 10.1201/9781003370864-6
- Bhardwaj, S.P. (1991). Biological management of *Brachycaudus helichrysi* (Kalt.) infesting almond in dry temperate region of Himachal Pradesh. *Journal of Aphidology*, 5, 26-31.
- Bhat, A., Sharma, P.L., Verma, S.C. & Chandel, V.G.S. (2024). Functional response of *Chrysoperla zastrowi sillemi* to greenpeach aphid, *Myzus persicae* Sulzer infesting capsicum, p. 203. In: *Extended Summaries-cum Proceedings of International Conference on Enabling Sustainable Food Systems through Natural Farming (ESFS-NF)* (Eds. Kumar P, Vashisth S, Chandel VGS, Sharma R, Verma S, Dev I, Chandel A and Chandel, R.S. Dr YS Parmar UHF in collaboration with INRAE and The Indian Ecological Society

- (Himachal Chapter) held at Solan (Nauni), Himachal Pradesh, India w.e.f. September 13-14, 2024, pp. 362
- Chandana, P.S., Sood, A. & Sharma, P.L. (2023). Functional response of green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen) to its prey, cabbage aphid, *Brevicoryne brassicae* L. *Journal of Biological Control*, 37(3), 177-180. doi: 10.18311/jbc/2023/35545
- Chauhan, N., Singh, C., Verma, S.C., Sharma, P.L., Chandel, R.S., Chandel, V.G.S., Sharma, V., Semwal, A. & Kalia, L. (2024). Biology and functional response of *Oenopia sauzeti* (Mulsant) on peach leaf curl aphid, *Brachycaudus helichrysi* (Kaltenbach). *Phytoparasitica*, 52:2, doi: 10.1007/s12600-023-01114-6
- Das, S.K. & Raychaudhuri, D. (1983). Parasitoids and predators of aphids (Homoptera: Aphididae) from India VI. New records of seven arachnids, one dipteran and neuropteran predators from Himachal Pradesh, India. *Entomon*, 8(1), 27-34.
- Devetak, D. & Klokočovník, V. (2016). The feeding biology of adult lacewings (Neuroptera): a review. *Trends in Entomology*, 12, 29-42.
- Devi, N., Raj, D. & Verma, S.C. (1996). Biology and feeding potential of *Coccinella septempunctata* Linn. on cabbage aphid, *Brevicoryne brassicae* Linn. *Journal of Entomological Research*, 20(1), 23-25.
- Dixit, Sharma, P.K., Jayaram, C.S., Rana, A. (2019). Population dynamics of wheat aphids and their natural enemies. *Indian Journal of Entomology*, 81(4), 916-920. doi: 10.5958/0974-8172.2019.00144.5
- Dixon, A.F.G. (2000). Insect predator-prey dynamics: ladybird beetles and biological control. Cambridge University Press, Cambridge, pp. 257.
- Emden, H.F.V., & Harrington, R. (2007). Aphids as crop pests. CABI. <https://doi.org/10.1079/9780851998190.0000>
- Gaikwad, M.B., Verma, S.C., Sharma, P.L., Chandel, R.S., Challa, N., Yankit, P. & Kedar, S.C. (2022). Functional response and predatory potential of coccinellid predator, *Oenopia kirbyi* Mulsant (Coccinellidae: Coleoptera) on rose aphid, *Macrosiphum rosae* L. (Aphididae: Hemiptera). *International Journal of Tropical Insect Science*, 42, 2233-2239. doi: 10.1007/s42690-022-00745-2
- Gautam, R.D. (1990). Mass multiplication technique of coccinellid predator, ladybird beetle (*Brumoides suturalis*). *Indian Journal of Agricultural Sciences*, 60(11), 747-750.
- Gupta, P.R. & Bhalla, O.P. (1993). Conservation of biotic agents in apple orchards of Himachal Pradesh. *Journal of Insect Science*, 6(2), 204-206.
- Hameed, S.F., Sud, V.K. & Kashyap, N.P. (1975). *Adonia variegata* (Goeze) (Coccinellidae: Coleoptera) an important predator of the Indian grain aphid *Macrosiphum miscanthi* Takah. in Kulu valley (HP). *Indian Journal of Entomology*, 37, 209-210.
- Hodek, I., Van Emden, H.F., Honek, I. (2012). Ecology and behavior of ladybird beetles (Coccinellidae). Blackwell Publishing Ltd., pp. 650. doi:10.1002/9781118223208
- Iperti, G. & Paoletti, M.G. (1999). Biodiversity of predaceous Coccinellidae in relation to bioindication and economic importance. Special issue: invertebrate biodiversity as bioindicators of sustainable landscapes. *Agriculture, Ecosystems & Environment*, 74, 323-342
- Kakar, K.L. (2006). Role of biotic agents in the management of rose aphid, *Sitobion rosaeformis* (Das) (Homoptera: Aphididae) in Himachal Pradesh. *Journal of Aphidology*, 20(1), 53-55
- Kakar, K.L. & Sood, A.K. (1989). Bioecological studies and control of rose aphid, *Macrosiphum rosaeformis* Das. *Journal of Aphidology*, 3, 113-118.
- Kasi, I.K. & Waiba, K.M. (2023). Biology of *Platynaspis saundersi* (Coleoptera: Coccinellidae). *Indian Journal of Entomology*, 85(3), 721-722. doi: 10.55446/IJE.2021.373

- Kharayat, S. & Kumari, U. (2021). Studies on different pests infesting cabbage and their management from two districts of Himachal Pradesh. *Journal of Entomology and Zoology Studies*, 9(6), 184-189.
- Kotwal, D.R., Bhalla, O.P. & Verma, A.K. (1984). Natural enemies of cabbage aphid, *Brevicoryne brassicae* (Linn.) in the mid-hill regions of Himachal Pradesh. *Indian Journal of Agricultural Science*, 54, 1011-1012.
- Kumar, B. & Omkar (2023). Ladybird beetles. In: *Insect Predators in Pest Management* (Ed. Omkar), CRC Press, Taylor and Francis Group, LLC, 187-228. doi: 10.1201/9781003370864-8
- Kumar, B. & Omkar. (2025). Prey-predator relationships in ladybird beetles and biological control of insect pests. *Journal of Applied Biosciences*, 51(1), 1-36. doi: 10.61081/joab/51v1i101
- Kumar, P., Thakur, T.S., Kumar, A. & Sharma, S. (2025). Records of insect pests attacking *Salix* spp. (willow) in the Spiti valley, Lahaul and Spiti, Himachal Pradesh. *International Journal of Farm Sciences*, 15(2), 1-8.
- Kumar, V. (2017). Management of woolly apple aphid, *Eriosoma lanigeraum* (Hausmann) using new insecticide molecules and biopesticides. M. Sc. (Ag.) thesis, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (Nauni), Himachal Pradesh. pp. 66.
- Kumari, D., Verma, S.C., Sharma, P.L. & Negi, S. (2020). Biology, feeding potential and functional response of *Chrysoperla zastrowisillemi* to cotton aphid, *Aphis gossypii* Glover. *Journal of Entomology and Zoology Studies*, 8(3), 381-386.
- Kumari, D., Verma, S.C., Sharma, P.L., Banshtu, T. & Nidhi (2021a). Biology and foraging behaviour of *Oenopia kirbyi* Mulsant (Coleoptera: Coccinellidae) on melon aphid, *Aphis gossypii* Glover. *Journal of Entomology and Zoology Studies*, 9(1), 1444-1448.
- Kumari, D., Verma, S.C., Sharma, P.L. & Gaikwad, M.B. (2021b). Biology, predatory potential and functional response of *Mallada desjardinsi* (Navas) on melon aphid, *Aphis gossypii* Glover. *International Journal of Tropical Insect Science*, 41, 495-501. doi: 10.1007/s42690-020-00233-5.
- Kumari, M. (2019). Records of predators of the green apple aphid, *Aphis pomi* DeGeer, from Himachal Pradesh. *Environment Conservation Journal*, 20(1&2), 31-33. doi: 10.36953/ECJ.2019.1008.1205
- Kumari, M., Bhardwaj, S. & Gautam, D.C. (2006). Coccinellid and syrphid predators of green apple aphid from Himachal Pradesh. 9th National Symposium on Recent Advances in Aphidology (November 27-29, 2006) held at Banaras Hindu University, Varanasi. pp. 16-17.
- Kumari, M., Vaidya, D. & Sharma, S. (2024). Studies on the biology and feeding capacity of *Coelophora saucia* (Mulsant), a significant predator of *Aphis pomi* de Geer, on apple hosts in Himachal Pradesh, India. *Environment Conservation Journal*, 25(3), 681–684. doi: 10.36953/ECJ.26232760
- Lakhanpal, G.C. & Raj, D. (1998). Predation potential of coccinellid and syrphid on important aphid species infesting rapeseed in Himachal Pradesh. *Journal of Entomological Research (New Delhi)*, 22(2), 181-190.
- Li, H., Wyckhuys, K.A.G. & Wu, K. (2023). Hoverflies provide pollination and biological pest control in greenhouse grown horticultural crops. *Frontiers in Plant Science*, 14, 1118388. doi: 10.3389/fpls.2023.1118388
- Makhmoo, H.D. & Verma, A.K. (1987). Bionomics of major aphidophagous syrphids occurring in mid-hill regions of Himachal Pradesh. *Journal of Biological Control*, 1: 23–31. doi: 10.18311/JBC/1987/15379
- Obrycki, J.J. & Kring, T.J. (1998). Predaceous Coccinellidae in biological control. *Annual Review of Entomology*, 43, 295-321.

- Omkar. 2023. Insect Predators in Pest Management (Ed.), CRC Press, Taylor & Francis Group, LLC, pp. 332. doi: 10.1201/9781003370864
- Palial, S., Verma, S.C., Sharma, P.L., Chandel, R.S., Kumar, A., Gupta, M., Sharma, N. & Sharma, P. (2022). Biology, predatory potential and growth parameters of the syrphid fly, *Scaeva pyrastris* (L.) (Diptera: Syrphidae) feeding on the cabbage aphid, *Brevicoryne brassicae* (L.). Egyptian Journal of Biological Pest Control, 32, 134. doi: 10.1186/s41938-022-00632-5
- Palial, S., Verma, S.C., Sharma, P.L., Chandel, R.S. & Antuj, S.S. (2023). Effect of prey density on the performance of *Eupeodes corollae* and its predation rate against the cabbage aphid, *Brevicoryne brassicae* (L.). Bulletin of Entomological Research, 113(5), 598-603. doi: 10.1017/S0007485323000275.
- Palial, S., Verma, S., Sharma, P., Chauhan, N. & Singh, C. (2025). Biological attributes and population growth parameters of five dominant syrphids against *Brevicoryne brassicae* infesting cabbage. Phytoparasitica, 53, 39. doi: 10.1007/s12600-025-01263-w
- Poddar, S.C. (1982). Studies on *Aphis craccivora* Koch and its natural enemies in some parts of India. Ph. D. thesis, Calcutta University, Kolkata, West Bengal, pp. 245. <http://hdl.handle.net/10603/162498>
- Poorani, J. (2002). A review of the genus *Oenopia* Mulsant (Coleoptera: Coccinellidae) of the Indian subcontinent, with description of a new species, Oriental Insects, 36(1), 97-116. doi: 10.1080/00305316.2002.10417328
- Rahman, K.A. (1940). Important insect predators of India. Proceedings of the Indian Academy of Sciences, 12, 67-74. doi: 10.1007/BF03049103
- Rao, V.P. (1969). Survey of natural enemies of aphids in India. Final Report of the Commonwealth Institute of Biological Control, 480: 1-93.
- Rawat, U.S. & Sangal, S.K. (1993). Influence of quality of food and host density on the ovipositional behaviour and longevity of predatory beetles, *Chilocorus bijugas* Mulsant. Journal of Insect Science, 6(1), 109-110.
- Semwal, A., Sharma, P.L., Verma, S.C., Chandel, V.G.S., Chauhan, N., Singh, C. & Chauhan, O. (2024). Natural enemy diversity for integrated pest management of cole crops in temperate zone of Himachal Pradesh, pp. 181-182. In: Extended Summaries-cum Proceedings of International Conference on Enabling Sustainable Food Systems through Natural Farming (ESFS-NF) (Eds. Kumar, P., Vashisth, S., Chandel, V.G.S., Sharma, R., Verma, S., Dev, I., Chandel, A. & Chandel, R.S.), Dr YS Parmar UHF in collaboration with INRAE and The Indian Ecological Society (Himachal Chapter) held at Solan (Nauni), Himachal Pradesh, India w.e.f. September 13-14, 2024, pp. 362.
- Sharma, D.C. & Kashyap, N.P. (2002). Impact of pesticidal spray on seasonal availability of natural predators and parasitoids in the tea ecosystem. Journal of Biocontrol, 16(1), 31-35.
- Sharma, H.C. & Adlakha, R.L. (1981). Predation potential of some coccinellids upon maize aphid, *Rhopalosiphum maidis* Fitch. Indian Journal of Ecology, 8(1), 118-121.
- Sharma, K.C. & Bhalla, O.P. (1988). Biology of six syrphid predators of cabbage aphid (*Brevicoryne brassicae*) on cauliflower (*Brassica oleracea* var. *botrytis*). Indian Journal of Agricultural Science, 58, 652-654.
- Sharma, K.C. & Bhalla, O.P. (1991). Predatory potential of syrphid species on different aphids of cruciferous crops in the mid hill regions of Himachal Pradesh. Indian Journal of Plant Protection, 19, 73-75.
- Sharma, P.K. & Verma, A.K. (1993). Studies on the coccinellid predators of the cabbage aphid *Brevicoryne brassicae* in Himachal Pradesh. Journal of Biological Control, 7(2), 15-19.
- Sharma, P.L., Chauhan, U. & Sharma, K.C. (2015). Studies on the diversity of predatory coccinellid beetles (Coleoptera) in different agro-climatic zones of himachal pradesh. The Bioscan, 10(3), 981-985.

- Sharma, P.L., Verma, S.C., Chandel, R.S., Chandel, R.P.S. & Thakur, P. (2017). An inventory of the predatory Coccinellidae of Himachal Pradesh, India. Journal of Entomology and Zoology Studies, 5 (6), 2503-2507.
- Sharma, R., Sood, A. & Sood, M. (2009). Coccinellid predators of *Aphis fabae* Scopoli infesting *Solanum nigrum* L. in Himachal Pradesh. Insect Environment, 15(2), 77.
- Sharma, S., Verma, S.C., Sharma, P. L. & Chandel, R. S. (2020). Diversity of insect-pests and their natural enemies in cauliflower under mid hills of Himachal Pradesh. Journal of Entomology and Zoology Studies, 8(2), 1204-1209.
- Siddiqui, R.K. & Krishnaswamy, S. (1972). Diptera: Syrphidae. In. Studies on predators of *Adelges* spp. in the Himalayas (Eds. Rao V.P. & Ghani, M.A.). Miscellaneous Publication of the Commonwealth Institute of Biological Control, No.3, pp. 14-22.
- Singh, C., Verma, S.C., Chandel, V.G.S. & Semwal, A. (2024). Agroecology harbouring a diverse range of natural enemies against *Eriosoma lanigerum* (Hausmann), pp. 173-174. In. Extended Summaries-cum Proceedings of International Conference on Enabling Sustainable Food Systems through Natural Farming (ESFS-NF) (Eds. Kumar P, Vashisth S, Chandel VGS, Sharma R, Verma S, Dev I, Chandel A and Chandel, R.S.), Dr YS Parmar UHF in collaboration with INRAE and The Indian Ecological Society (Himachal Chapter) held at Solan (Nauni), Himachal Pradesh, India w.e.f. September 13-14, 2024, pp. 362
- Singh, C., Verma, S.C., Sharma, P.L., Chandel, V.G.S., Chandel, R.S., Chauhan, N. & Semwal, A. (2025). Assessing the predation dynamics of three coccinellid species on *Myzus persicae* (Sulzer): a functional response perspective Bulletin of Entomological Research, 115(4):1-7. doi: 10.1017/S0007485325000331
- Singh, D. & Bali, R. (1993). New records of coccinellid predators on aphids (*Aphis affinis* and *Myzus persicae*) in Japanese mint (*Mentha arvensis* subsp. *Haplocalyx* var. *piperascens*) and Egyptian henbane (*Hyoscyamus muticus*). Indian Journal of Agricultural Science, 63, 313-314.
- Singh, P., Thakur, M., Sharma, K.C., Sharma, H.K. & Nayak, R.K. (2020). Larval feeding capacity and pollination efficiency of the aphidophagous syrphids, *Eupeodes frequens* (Matsmura) and *Episyrphus balteatus* (De Geer) (Diptera: Syrphidae) on the cabbage aphid (*Brevicoryne brassicae* L.) (Homoptera: Aphididae) on mustard crop. Egyptian Journal of Biological Pest Control, 30, 105: 1-9. doi: 10.1186/s41938-020-00300-6
- Singh, R. (2025a). A catalogue of tri-trophic associations of aphidophagous arthropods in Uttar Pradesh, India. Uttar Pradesh Journal of Zoology, 46(19), 158-179. 10.56557/upjoz/2025/v46i195276
- Singh, R. (2025b). Species diversity and tri-trophic associations of aphidophagous Coccinellidae (Coleoptera: Insecta) in India. Uttar Pradesh Journal of Zoology, 46(18), 225-241. doi: 10.56557/upjoz/2025/v46i185253.
- Singh, R. (2026a). An updated checklist of tri-trophic associations of aphidophagous ladybirds (Coccinellidae: Coleoptera) in different districts of Uttarakhand, India. Munis Entomology & Zoology, 21(1), 537-567.
- Singh, R. (2026b). Catalogue of tri-trophic associations among aphids (Hemiptera: Aphididae), their predators, and host plants across the districts of Manipur, India. Munis Entomology & Zoology, 21(2), 1870-1915.
- Singh, R. (2026c). Tri-trophic associations of aphidophagous hover flies (Syrphidae: Diptera) in different states and union territories of India. Munis Entomology & Zoology, 21(1), 373-403.
- Singh, R. & Agrawal, R. (2026). A catalogue of tri-trophic associations of aphidophagous arthropods in Karnataka, India. Munis Entomology & Zoology, 21(2), 1683-1724.
- Singh, R. & Bhagat, R. C. (2026). An updated checklist of tri-trophic associations of aphidophagous ladybirds (Coleoptera: Coccinellidae) in Jammu & Kashmir and Ladakh territories of India. Munis Entomology & Zoology, 21(1), 795-833.

- Singh, R. & Omkar (2025). An updated checklist of tri-trophic associations of aphidophagous Diptera and Neuroptera in different districts of Uttarakhand, India. *Journal of Applied Bioscience*, 51(2): 35-55. doi: 10.61081/joab/51v2i102
- Singh, R. & Shukla, A. (2026a). An updated tri-trophic associations of the aphidophagous arthropods in West Bengal, India. *Arthropods*, 15(2): 90-135.
- Singh, R. & Shukla, A. (2026b). A catalogue of tri-trophic associations of aphidophagous arthropods in Gujarat, India. *Journal of Applied Entomologist*, 6(1):15-25. <https://doi.org/10.64171/JAE.6.1.15-25>
- Singh, R. & Shukla, A. (2026c). An updated checklist of tri-trophic associations of arthropod predators of aphids (Homoptera: Aphididae) in different districts of Kerala, India. *Journal of Biological Control*, 40(2), in press.
- Singh, R. & Singh, G. (2016). Aphids and their biocontrol. In: *Ecofriendly Pest Management for Food Security* (Ed. Omkar), Academic Press, pp. 63-108. doi: 10.1016/B978-0-12-803265-7.00003-8
- Singh, R. & Singh, G. (2022). Reproductive strategies in aphids. In: *Reproductive strategies in insects* (Eds. Omkar & Mishra, G.), Taylor. & Francis Group, LLC, pp. 259-282. doi: 10.1201/9781003043195-13
- Singh, R. & Srivastav, A.K. (2025). An updated checklist of tri-trophic associations of aphidophagous arthropods in different districts of Uttarakhand, India. *International Journal of Zoological Investigations*, 11(2): 810-826.
- Singh, R., Bhagat, R.C. & Singh, A. (2025). An updated checklist of tri-trophic associations of aphidophagous predatory arthropods in Jammu & Kashmir and Ladakh, India. *Uttar Pradesh Journal of Zoology*, 46(21), 177-98. doi: 10.56557/upjoz/2025/v46i215339.
- Singh, R., Singh, B.B. & Sharma, A.K. (2024a). Checklist of aphidophagous spiders (Araneae: Arachnida: Arthropoda) in India. *Serket*, 20(3), 288-310.
- Singh, R., Tiwari A.K. and Tiwari K.M. (2024b). Checklist of aphidophagous Neuroptera (Insecta: Arthropoda) in India. *International Journal of Biological Innovations*, 6(2), 99-127. doi: 10.46505/IJBI.2024.6204
- Singh, S.P. (1993). Biological control of insect pests. In: *Advances in Horticulture Vol. 3- Fruit crops: Part 3* (Eds. Chadha, K.L. & Pareek, O.P.), Malhotra Publishing House, New Delhi, India, pp. 1591-1615.
- Soni, S., Kumar, S., Sood, A.K. & Rana, R. S. (2021). Modeling of aphid complex and its associated natural enemies in rapeseed-mustard in relation to climatic factors. *Journal of Agrometeorology*, 23(2), 207-212.
- Sood, A., Kapoor, K.S., Verma, J.S., Sharma, K.C. & Sood, M. (2007). Feeding potential different species of syrphid larva on *Aphis fabae* Scopoli infesting *Solanum nigrum* in midhills of Himachal Pradesh. *Journal of Biological Control*, 21 (Special), 51-53. doi: 10.18311/jbc/2007/15034
- Thakur, J.N. & Pawar, A.D. (1986). New records of *Syrphus confinator* Wiedemann and *Chrysopa* sp. as predators of apple woolly aphid, *Eriosoma lanigerum* Hausmann from Kullu valley (H.P.) India. *National Academy of Sciences, India, Science Letters*, 9(3), 91-92.
- Thakur, J.N., Pawar, A.D. & Rawat, U.S. (1988). Observations on the correlation between population density of apple woolly aphid and its natural enemies and their effectiveness in Kullu Valley (H.P.). *Plant Protection Bulletin*, 40(2), 13-15.
- Thakur, J.N., Rawat, U.S., Pawar, A.D. & Sidhu, S.S. (1989). Natural enemy complex of the cabbage aphid *Brevicoryne brassicae* L. (Homoptera: Aphididae) in Kullu Valley, Himachal Pradesh. *Journal of Biological Control*, 3(1), 69.
- Thakur, M. & Chandla, V.K. (2013). Species composition and abundance of natural enemies of *Myzus Persicae* (Sulzer) in potato agro-ecosystem in Shimla hills. *Journal of Ecofriendly agriculture*, 8(1), 56-60.

- Thakur, S., Sharma, P.K. & Sharma, P.C. (2022). Predation potential of ladybird beetle, *Coccinella septempunctata* (Linnaeus) (Coleoptera: Coccinellidae) against aphids infesting wheat. *Himachal Journal of Agricultural Research*, 48(1), 139-141.
- Trivedi, T.P. & Rajagopal, D. (1988). Natural enemies of potato aphids, *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover (Homoptera: Aphididae) in India. *Biocovas*, 1, 173-177.
- Vashisth, S., Sharma, U., Gautam, N. & Verma, S. (2022). Apple pest management under climate change scenario in dry temperate zone (Spiti): strategies, prospects and limitations. *Environment and Ecology*, 40(3D), 1829–1837.
- Verma, A.K. & Makhmoor, H.D. (1987). Relative abundance of syrphid predators of *Brevicoryne brassicae* (L.) in cauliflower seed crop ecosystem. *Journal of Biological Control*, 1, 98- 103. doi:10.18311/jbc/1987/15422
- Verma, J.S., Sharma, K.C., Sood, A. & Sood, M. (2005). Biology and predatory potential of syrphid predators on *Aphis fabae* infesting *Solanum nigrum* L. *Journal of Entomological Research*, 29, 39-41.
- Verma, K.L. & Chowdhuri, A.N. (1975). Predaceous coccinellids on peach curl aphid, *Brachycaudus helichrysi* Kalt. from Mashobra (Himachal Pradesh). *Himachal Journal of Agricultural Research*, 3, 38-39.
- Verma, K.L. & Singh, M. (1985). Some biological agents associated with the suppression of apple pests in Himachal Pradesh. *Pesticides*, 19, 54.
- Vishwajeet (2020). Population dynamics of insect-pests of brinjal and their natural enemies under Subhash Palekar Natural Farming and Conventional Farming Systems. M. Sc. (Agric.) thesis, Dr. Yashwant Singh Parmar University of Horticulture and Forestry Solan (Nauni), Himachal Pradesh, India, pp. 57.