Article

A catalogue of tri-trophic associations among aphidiine parasitoids (Hymenoptera: Braconidae), aphids (Homoptera: Aphididae), and host plants in Uttarakhand, India

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Abstract

The present study documents the tri-trophic associations among aphidiine parasitoids, aphid hosts, and host plants in Uttarakhand. A total of 51 parasitoid taxa were recorded in association with 59 aphid species infesting 69 host plant species, forming 131 tri-trophic associations (triplets). Species of *Aphidius* were dominant, with *Aphidius matricariae* exhibiting the widest host range (10 triplets), while *Binodoxys indicus* showed the highest ecological associations (12 triplets). *Diaeretiella rapae* also demonstrated broad host associations. In contrast, many parasitoid taxa exhibited high host specificity, being associated with only a single aphid and host plant species. Among aphids, *Aphis gossypii* showed the greatest ecological diversity, forming 10 triplets, followed by *Brachycaudus helichrysi* and *Sitobion miscanthi* with 7 triplets each. Most aphid species, however, displayed narrow ecological associations. Among host plants, *Cestrum nocturnum* and *Rosa* spp. supported the highest number of triplets (7 each), while economically important brassicaceous and cereal crops harboured several parasitoid-associated aphid species. Overall, the study reveals considerable diversity and complexity in aphidiine parasitoid-aphid-host plant interactions in Uttarakhand, comprising both highly specialised and broadly polyphagous species. The findings provide valuable baseline information for ecological studies, biodiversity assessment, and biological control programmes in Himalayan agroecosystems.

Keywords tri-trophic interactions; aphidiine parasitoids; checklist; host plants; aphids; Braconidae; biodiversity conservation.

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1 Introduction

Aphids (Hemiptera: Aphididae) constitute one of the most destructive groups of phytophagous insects associated with agricultural, horticultural, and forest ecosystems throughout the world (Blackman and Eastop, 2000; van Emden and Harrington, 2017; Singh et al., 2023). These soft-bodied sap feeders infest a wide range

of cultivated and wild plant species and cause severe economic losses through direct feeding, depletion of plant nutrients, distortion of plant tissues, and transmission of numerous plant viruses (Singh and Singh, 2021). Their high reproductive potential, rapid parthenogenetic multiplication, short generation time, and ability to exploit diverse host plants enable aphids to attain outbreak populations within a short period, particularly under favorable environmental conditions (Dixon, 1998; Singh and Singh, 2022). In agricultural and horticultural crops, aphid infestations result in reduced plant vigor, diminished yield, and deterioration of product quality, whereas in forest ecosystems they adversely affect the growth and survival of economically important tree species (Blackman and Eastop, 2006). Consequently, aphids are regarded as key pests in diverse agroecosystems and natural habitats.

The ecological impact of aphids is, however, balanced to a considerable extent by a rich assemblage of their natural enemies comprising predators, parasitoids, and pathogens (Starý, 1970; Hodek and Honěk, 1996; Singh and Singh, 2016). Among these, aphidiine parasitoids (Hymenoptera: Braconidae: Aphidiinae) are recognised as one of the most specialised and effective biological control agents of aphids (Starý, 1988; Singh and Singh, 2016). Aphidiine parasitoids are solitary endoparasitoids that oviposit inside aphid hosts, where the developing larva ultimately kills the host and forms a characteristic “mummy” (Starý, 1988; Singh and Agarwala, 1992). These parasitoids play a vital role in regulating aphid populations under both natural and managed ecosystems and are therefore considered integral components of integrated pest management programs (Hågvar and Hofsvang, 1991; Boivin et al., 2012). Several aphidiine species have been successfully utilised in augmentative and classical biological control strategies against economically important aphids in field crops, vegetable crops, fruit orchards, ornamental plants, and forest nurseries (van Lenteren, 2012; Singh and Singh, 2016; Toledo-Hernández et al., 2024).

The interactions among aphids, their parasitoids, and host plants represent complex tri-trophic associations that are fundamental to the functioning of terrestrial ecosystems (Price et al., 1980). Host plants not only provide food and habitat for aphids but also indirectly influence parasitoid behaviour, host selection, distribution, and efficiency through plant morphology, nutritional quality, allelochemicals, and herbivore-induced volatiles (Vet and Dicke, 1992; Singh, 2003; Ode, 2006). Similarly, aphid species differ in their suitability, defensive mechanisms, and host specificity toward parasitoids, thereby shaping parasitoid diversity and community structure (Godfray, 1994). Understanding these tri-trophic interactions is therefore essential for elucidating ecological relationships, host specificity, coevolutionary processes, and trophic network dynamics in agroecosystems and forest habitats.

Documentation of tri-trophic associations involving aphidiine parasitoids, aphids, and host plants has gained increasing importance in recent years because such information provides a scientific basis for biodiversity assessment, ecological monitoring, and development of sustainable pest management strategies (Gagic et al., 2016; Singh and Agarwala, 2026; Singh and Bhagat, 2026; Singh and Shukla, 2026). Comprehensive knowledge of parasitoid-aphid-plant relationships helps identify dominant parasitoid species, key aphid pests, and important reservoir host plants that support natural enemy populations across seasons (Starý and Ghosh, 1983; Singh et al., 2026). Furthermore, these associations contribute to conservation biological control by facilitating habitat manipulation and enhancing ecosystem services provided by parasitoids in agricultural landscapes (Landis et al., 2000).

Despite the ecological and economic significance of aphidiine parasitoids, information on their host associations and host plant relationships remains fragmented in many regions. Existing studies are often restricted to individual crops, limited geographical areas, or economically important aphid species, resulting in inadequate understanding of the broader parasitoid-aphid-plant interaction networks. Therefore, systematic investigations on tri-trophic associations are necessary to reveal the diversity, distribution, and ecological

relationships of aphidiine parasitoids across different ecosystems. In this context, the present study aims at compiling a comprehensive and taxonomically validated checklist of tri-trophic associations among aphids, their parasitoids, and host plants in Uttarakhand.

2 Materials and Methods

Uttarakhand (30.0668°N, 79.0193°E), situated in the northern Himalayan region of India, is bordered by the Tibet Autonomous Region of China in the north, Nepal in the east, Uttar Pradesh in the south, and Himachal Pradesh in the west and northwest (Fig. 1). Covering an area of about 53,483 km², the state is predominantly mountainous, with nearly 86% of its landscape comprising hilly terrain and around 65% under forest cover. Administratively, Uttarakhand is divided into the Kumaon and Garhwal divisions. The Kumaon division includes the districts of Almora, Bageshwar, Champawat, Nainital, Pithoragarh, and Udham Singh Nagar, whereas the Garhwal division comprises Chamoli, Dehradun, Haridwar, Pauri Garhwal, Rudraprayag, Tehri Garhwal, and Uttarkashi. The northern part of the state is marked by high Himalayan peaks and extensive glaciers that give rise to major river systems such as the Ganges and Yamuna. Uttarakhand is also renowned for its ecologically significant protected areas, notably Jim Corbett National Park and Valley of Flowers National Park. The state exhibits considerable climatic heterogeneity, ranging from subtropical conditions in the foothills to temperate and alpine climates at higher elevations. Annual rainfall averages approximately 1,550 mm, while temperatures vary from about -4°C in colder regions to 43°C in the plains. Such pronounced altitudinal and climatic variation supports a rich and diverse assemblage of flora and fauna (Kharkwal, 2017).

This catalogue of tri-trophic associations involving aphidophagous arthropods in Uttarakhand has been compiled using information available from recently published books, peer-reviewed research articles, authenticated theses, and reliable online databases up to 30 April 2026. Earlier literature often contained inconsistencies and inaccuracies in the scientific names of predators, aphids, and host plants, including in several recent publications. These discrepancies are primarily attributable to ongoing taxonomic revisions, nomenclatural changes, and continued reliance on outdated literature sources. Furthermore, sustained investigations on predator-prey interactions and biodiversity frequently yield new distributional records, revised taxonomic statuses, and updated species nomenclature. In the present compilation, special attention has been given to minimising such errors through careful verification and standardisation of taxonomic information. Aphid nomenclature has been updated following the Aphid Species File (https://aphid.speciesfile.org), whereas host plant names have been standardised according to World Flora Online (https://www.worldfloraonline.org) and the Global Biodiversity Information Facility (https://www.gbif.org).

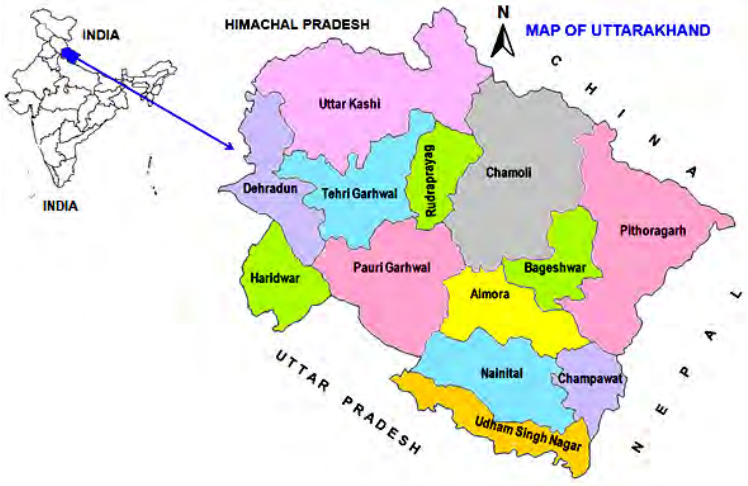

Fig. 1 Geographic location of the state of Uttarakhand within India, highlighted in blue shading.

3 Results

The analysis of aphidiine parasitoid-aphid-host plant associations in Uttarakhand revealed the occurrence of 51 parasitoid taxa associated with 59 aphid species infesting 69 host plant species, forming a total of 131 tri-trophic associations (triplets) (Table 1). Among the recorded parasitoids, species of *Aphidius* were predominant, represented by 16 taxa. *Aphidius matricariae* exhibited the widest host range, parasitising 8 aphid species on 8 host plants and forming 10 triplets. *Binodoxys indicus* showed the maximum ecological associations, being linked with 6 aphid species on 10 host plants and accounting for 12 triplets. *Diaeretiella rapae* also showed broad associations with 3 aphid species on 7 host plants, forming 9 triplets. Moderately polyphagous species included *Aphidius asteris* (5 aphid species, 5 triplets), *Aphidius uzbekistanicus* (4 aphid species, 6 triplets), *Aphidius qadrii* (4 aphid species, 4 triplets), *Aphidius* spp. (5 triplets), and *Aphidius rhopalosiphi* (4 triplets). Similarly, *Aphidius colemani*, *Lipolexis oregmae*, and *Ephedrus srinagarensis* formed 4 triplets each. In contrast, a large proportion of parasitoids exhibited narrow host specificity. More than half of the recorded taxa, including *Adialytus salicaphis*, *Aphidius smithi*, *Aphidius staryi*, *Aphidius urticae*, *Archaphidus greenideae*, *Binodoxys mackaueri*, *Cristicaudus indicus*, *Pauesia orientalis*, *Praon himalayensis*, and *Toxares* sp., were associated with only a single aphid species on a single host plant species.

Overall, the results indicate considerable diversity and complexity of aphidiine parasitoid-aphid-host plant interactions in Uttarakhand, comprising both highly specialised and broadly polyphagous parasitoid species within the Himalayan ecosystem.

Table 1 Number of species of aphidiine parasitoids parasitising on different number of aphid species infesting different number of host plant species and triplets in Uttarakhand.

Parasitoid species		Number of		
		Aphid species	Plant species	Triplets
1.	*Adialytus ambiguus*	2	2	2
2.	*Adialytus salicaphis*	1	1	1
3.	*Aphidius asteris*	5	3	5
4.	*Aphidius cingulatus*	2	2	4
5.	*Aphidius colemani*	3	4	4
6.	*Aphidius eglanteriae*	3	3	3
7.	*Aphidius matricariae*	8	8	10
8.	*Aphidius polycostulari*	1	1	1
9.	*Aphidius qadrii*	4	4	4
10.	*Aphidius rhopalosiphi*	3	3	4
11.	*Aphidius rosae*	2	1	2
12.	*Aphidius smithi*	1	1	1
13.	*Aphidius staryi*	1	1	1
14.	*Aphidius urticae*	1	1	1
15.	*Aphidius uzbekistanicus*	4	5	6
16.	*Aphidius* spp.	4	4	5
17.	*Archaphidus greenideae*	1	1	1
18.	*Betuloxys intermedius*	2	2	3
19.	*Binodoxys centaureae*	1	1	2
20.	*Binodoxys indicus*	6	10	12
21.	*Binodoxys joshimathensis*	1	2	2
22.	*Binodoxys mackaueri*	1	1	1

Parasitoid species		Number of		
		Aphid species	Plant species	Triplets
23.	*Binodoxys rubicola*	1	1	1
24.	*Binodoxys sinensis*	2	1	2
25.	*Binodoxys takecallis*	1	1	1
26.	*Binodoxys tomentosae*	1	1	1
27.	*Cristicaudus garhwalensis*	2	2	2
28.	*Cristicaudus indicus*	1	1	1
29.	*Diaeretiella rapae*	3	7	9
30.	*Ephedrus lacertosus*	2	1	2
31.	*Ephedrus laevicollis*	1	1	1
32.	*Ephedrus nacheri*	2	2	2
33.	*Ephedrus persicae*	1	1	1
34.	*Ephedrus ramnagarensis*	1	1	1
35.	*Ephedrus srinagarensis*	2	2	4
36.	*Ephedrus* spp.	2	2	2
37.	*Kashmiria aphidis*	2	1	2
38.	*Lipolexis oregmae*	3	3	4
39.	*Lysaphidus* sp.	1	1	1
40.	*Lysiphlebia japonica*	1	1	1
41.	*Lysiphlebus confusus*	1	1	1
42.	*Pauesia lachniella*	2	2	2
43.	*Pauesia orientalis*	1	1	1
44.	*Praon abjectum*	1	1	1
45.	*Praon himalayensis*	1	1	1
46.	*Praon orientale*	2	2	3
47.	*Praon pubescens*	1	1	1
48.	*Praon volucre*	2	2	2
49.	*Praon* spp.	2	2	2
50.	*Toxares* sp.	1	1	1
51.	*Trioxys* spp.	3	3	3
	Total	**59**	**69**	**131**

Among the aphids, *Aphis gossypii* showed high ecological diversity, infesting 7 host plant species and associated with 4 parasitoid species, forming the highest number of triplets (10). Similarly, *Brachycaudus helichrysi* was recorded on 6 host plants with 5 parasitoid species and 7 triplets, while *Sitobion miscanthi* occurred on 4 host plant species and was associated with 4 parasitoid species, accounting for 7 triplets (Table 2). Several aphid species exhibited moderate levels of parasitoid association. *Lipaphis erysimi* was associated with 2 parasitoid species on 4 host plants, forming 5 triplets. *Capitophorus* spp., *Sitobion rosaeiformis*, and *Uroleucon* spp. each showed associations with multiple parasitoids and host plants, contributing 4 triplets each. Likewise, *Prociphilus himalayaensis* formed 3 triplets involving 2 host plants and 2 parasitoid species. In contrast, the majority of aphid taxa exhibited narrow ecological associations. More than half of the recorded aphid species, including *Acyrthosiphon pisum*, *Aphis fabae*, *Aphis nerii*, *Cavariella aegopodii*, *Cinara*

maculipes, *Macrosiphum rosae*, *Myzus persicae*, *Panaphis juglandis*, and *Phorodon cannabis*, were associated with only a single host plant species and a single parasitoid species, each forming one triplet in Uttarakhand.

Table 2 Species of aphids infesting varying numbers of host plant species, along with the corresponding parasitoid species and tritrophic associations in Uttarakhand.

Aphid species	Number of		
	Plant species	Parasitoid species	Triplets
1. *Acyrthosiphon pisum*	1	1	1
2. *Acyrthosiphon* sp.	2	2	2
3. *Aphis craccivora*	2	4	4
4. *Aphis fabae*	1	1	1
5. *Aphis farinosa*	1	1	1
6. *Aphis gossypii*	7	4	10
7. *Aphis longisetosa*	1	1	1
8. *Aphis nasturtii*	1	1	1
9. *Aphis nerii*	1	1	1
10. *Aphis* spp.	8	6	8
11. *Brachycaudus helichrysi*	6	5	7
12. *Brachycaudus* sp.	2	2	2
13. *Brevicoryne brassicae*	3	1	3
14. *Capitophorus carduinus*	1	1	1
15. *Capitophorus formosartemisiae*	3	4	4
16. *Capitophorus* spp.	4	3	4
17. *Cavariella aegopodii*	1	1	1
18. *Chaitophorus* sp.	1	1	1
19. *Cinara maculipes*	1	1	1
20. *Cinara tujafilina*	1	1	1
21. *Eutrichosiphum* sp.	1	1	1
22. *Hayhurstia atriplicis*	1	2	2
23. *Hyalopterus pruni*	2	1	2
24. *Lachnus tropicalis*	1	1	1
25. *Liosomaphis himalayensis*	1	1	1
26. *Lipaphis erysimi*	4	2	5
27. *Macrosiphoniella kikungshana*	1	1	1
28. *Macrosiphoniella pseudoartemisiae*	1	2	2
29. *Macrosiphoniella sanborni*	1	2	2
30. *Macrosiphoniella yomogifoliae*	1	1	1
31. *Macrosiphoniella* spp.	3	2	3
32. *Macrosiphum rosae*	1	1	1
33. *Macrosiphum* sp.	1	1	1
34. *Melanaphis donacis*	1	1	1
35. *Melanaphis meghalayensis meghalayensis*	1	1	1
36. *Melanaphis* nr. *arundinariae*	1	1	1
37. *Melanaphis sacchari*	1	1	1

Aphid species	Number of		
	Plant species	Parasitoid species	Triplets
38. *Melanaphis* sp.	1	1	1
39. *Myzus cornutus*	1	1	1
40. *Myzus dycei*	1	1	1
41. *Myzus ornatus*	1	1	1
42. *Myzus persicae*	1	1	1
43. *Myzus siegesbeckicola*	1	1	1
44. *Myzus sorbi*	1	3	3
45. *Nasonovia* sp.	1	1	1
46. *Panaphis juglandis*	1	1	1
47. *Phorodon cannabis*	1	1	1
48. *Prociphilus himalayaensis*	2	2	3
49. *Prociphilus* spp.	2	2	3
50. *Pterocomma* sp.	2	1	2
51. *Schizaphis* spp.	2	2	3
52. *Shinjia orientalis*	1	2	2
53. *Sipha maydis*	1	1	1
54. *Sitobion miscanthi*	4	4	7
55. *Sitobion rosaeiformis*	2	4	4
56. *Sitobion* spp.	2	3	3
57. *Takecallis affinis affinis*	1	2	2
58. *Uroleucon sonchi*	1	1	1
59. *Uroleucon* spp.	2	3	4
60. Unidentified species	2	2	2
Total	**69**	**51**	**131**

Among the host plants, *Cestrum nocturnum* and *Rosa* spp. supported the highest number of tri-trophic associations, each accounting for 7 triplets. *Cestrum nocturnum* was associated with 2 aphid species and 4 parasitoid taxa, whereas *Rosa* sp. harboured 4 aphid species and 5 parasitoid taxa. *Artemisia vulgaris* showed high parasitoid diversity, being associated with 3 aphid species and 5 parasitoid taxa, forming 5 triplets. Similarly, *Bambusa* sp., *Bothriochloa* spp., *Lonicera quinquelocularis*, and *Sorbaria tomentosa* each contributed 4 triplets involving multiple aphid and parasitoid species. *Triticum aestivum* and *Rumex* sp. were associated with 3 parasitoid taxa each, while *Chrysanthemium* sp. and *Sonchus* spp. formed 2-3 triplets. Several economically important crop plants also supported notable parasitoid associations. Brassicaceous plants including *Brassica juncea*, *Brassica rapa*, *Brassica oleracea* var. *botrytis*, and *Raphanus sativus* were associated mainly with *Diaeretiella rapae* and other aphidiines through aphids such as *Lipaphis erysimi* and *Brevicoryne brassicae*. Cereal and grass hosts including *Triticum aestivum*, *Avena sativa*, *Bothriochloa* spp., and *Cenchrus flaccidus* supported parasitoids associated with *Sitobion* and *Schizaphis* species. In contrast, the majority of host plants exhibited narrow associations, with nearly half of the plant taxa linked to only a single aphid species and a single parasitoid species, forming one triplet each. Examples include *Pisum sativum*, *Juglans regia*, *Pinus wallichiana*, *Cannabis sativa*, *Calotropis procera*, and *Thuja* sp.

Table 3 Species of plants infested by varying numbers of aphid species, along with the corresponding parasitoid species and tritrophic associations in Uttarakhand.

Host plant species	Number of		
	Aphid species	Parasitoid species	Triplets
1. *Anaphalis margaritacea*	1	1	1
2. *Anaphalis* sp.	1	1	1
3. *Artemisia* spp.	4	3	4
4. *Artemisia vestita*	2	1	2
5. *Artemisia vulgaris*	3	5	5
6. *Avena sativa*	1	1	1
7. *Bambusa* sp.	3	3	4
8. *Berberis* sp.	1	1	1
9. *Bidens pilosa*	1	1	1
10. *Bothriochloa* spp.	3	3	4
11. *Brassica juncea*	2	1	2
12. *Brassica oleracea* var. *botrytis*	1	1	1
13. *Brassica rapa*	1	2	2
14. *Brassica* sp.	2	1	2
15. *Calotropis procera*	1	1	1
16. *Cannabis sativa*	1	1	1
17. *Capsicum* sp.	1	1	1
18. *Cenchrus flaccidus*	1	1	1
19. *Cestrum nocturnum*	2	4	7
20. *Chenopodium album*	1	2	2
21. *Chrysanthemium* sp.	2	2	3
22. *Cirsium wallichii*	1	1	1
23. *Cotoneaster* sp.	2	1	2
24. *Cucumis melo*	1	1	1
25. *Cucurbita* sp.	1	1	1
26. *Cynodon dactylon*	1	1	1
27. *Datura stramonium*	1	1	1
28. *Euphorbia pilosa*	1	1	1
29. Fern	1	2	2
30. *Gnaphalium* sp.	1	1	1
31. *Hibiscus rosasinensis*	1	1	1
32. *Juglans regia*	1	1	1
33. *Lablab purpureus purpureus*	2	1	2
34. *Lithocarpus dealbatus*	1	1	1
35. *Lonicera quinquelocularis*	2	2	4
36. *Phragmites* sp.	1	1	1
37. *Phyllanthus velutinus*	1	1	1
38. *Pinus wallichiana*	1	1	1
39. *Pisum sativum*	1	1	1
40. *Populus ciliata*	2	1	2

Host plant species	Number of		
	Aphid species	Parasitoid species	Triplets
41. *Prunus amygdalus*	1	2	2
42. *Prunus cornuta*	1	1	1
43. *Prunus persica*	2	2	2
44. *Psidium guajava*	1	1	1
45. *Pyrus pashia*	2	2	2
46. *Pyrus* sp.	2	1	2
47. *Quercus* sp.	1	1	1
48. *Raphanus sativus*	1	1	1
49. *Rosa* sp.	4	5	7
50. *Rubus ellipticus*	1	1	1
51. *Rubus* sp.	1	1	1
52. *Rumex* sp.	2	3	3
53. *Saccharum officinarum*	1	1	1
54. *Salix aegyptiaca*	1	1	1
55. *Salix caprea*	1	1	1
56. *Salix hastata*	1	1	1
57. *Salix tetrasperma*	2	1	2
58. *Senecio* sp.	2	1	2
59. *Solanum nigrum*	2	1	2
60. *Solanum* sp.	1	1	1
61. *Sonchus arvensis*	2	1	2
62. *Sonchus* sp.	2	1	2
63. *Sorbaria tomentosa*	2	4	4
64. *Strobilanthes* sp.	1	1	1
65. *Strobilanthes wallichii*	1	1	1
66. *Thuja* sp.	1	1	1
67. *Triticum aestivum*	1	3	3
68. *Urtica dioica*	2	1	2
69. *Verbascum* sp.	1	1	1
70. Unidentified species	6	6	6
Total	**59**	**51**	**131**

4 Discussion

The present study revealed a highly diverse network of aphidiine parasitoid–aphid–host plant interactions in Uttarakhand, comprising 51 parasitoid taxa, 59 aphid species, 69 host plant species, and 131 tri-trophic associations. The remarkable diversity observed in the region is strongly influenced by the unique climatic conditions of the western Himalaya, characterised by pronounced altitudinal gradients, wide variation in temperature and rainfall, high humidity in many localities, and distinct seasonal regimes. These climatic heterogeneities create a mosaic of microhabitats that support diverse vegetation types and prolonged availability of aphid hosts, thereby favouring the establishment and persistence of a rich aphidiine fauna (Das and Chakrabarti, 1991a; Chakrabarti and Debnath, 2009; Sarkar, 2022). The cool temperate to subtropical

climatic zones prevailing across different elevations further promote niche differentiation and seasonal succession among aphid and parasitoid species. The predominance of *Aphidius* species agrees with reports from West Bengal (Singh and Agarwala, 2026), Uttar Pradesh (Singh et al., 2026a), Jammu & Kashmir (Singh and Bhagat, 2026), Manipur (Singh and Shukla, 2026a), and other Himalayan regions where favourable climatic conditions and diverse host availability support the dominance of this genus (Raychaudhuri et al., 1982; Das and Chakrabarti, 1991a). Broadly polyphagous parasitoids such as *Aphidius matricariae*, *Binodoxys indicus*, and *Diaeretiella rapae* exhibited extensive associations with multiple aphid and host plant species, probably owing to their high ecological adaptability and tolerance to varying climatic conditions, coupled with wide host acceptance (Starý, 1970; Rakhshani et al., 2012). Similar trends have also been documented in the agro-climatic conditions of West Bengal (Singh and Agarwala, 2026) and Uttar Pradesh (Singh et al., 2026a).

The strong association of *Diaeretiella rapae* with brassicaceous crops observed in the present study is consistent with earlier reports from Bihar (Ahmad and Singh, 1997), Gujarat (Kavad and Korat, 2013), Karnataka (Singh et al., 2026b), Manipur (Subhrani et al., 2010; Singh and Shukla, 2026a), Punjab (Atwal et al., 1969; Kumar, 2015), and Uttar Pradesh (Singh et al., 2026a), as well as from several regions worldwide (Singh and Singh, 2015). The parasitoid is widely recognised as an important natural enemy of the mustard aphid, *Lipaphis erysimi*, and the cabbage aphid, *Brevicoryne brassicae*, thereby playing a significant role in the biological control of aphids infesting cruciferous crops. Likewise, cereal-associated parasitoids such as *Aphidius uzbekistanicus* and *Aphidius rhopalosiphi* were linked mainly with *Sitobion* and *Schizaphis* species on graminaceous hosts, indicating the importance of grassland and cereal habitats in sustaining parasitoid diversity (Das and Chakrabarti, 1989a; Chakraborty and Chakrabarty, 1994).

In contrast, many parasitoids and aphids exhibited narrow host specificity, a pattern commonly associated with montane ecosystems where ecological isolation and specialised host relationships promote niche differentiation (Starý, 1970; Das and Chakrabarti, 1991a). Similar specialised associations have also been reported from northeastern Himalayan regions and West Bengal (Das and Chakrabarti, 1991b; Chakrabarti et al., 2002).

Host plants such as *Cestrum nocturnum*, *Rosa* spp., and *Artemisia vulgaris* supported high parasitoid diversity, likely because they harbour multiple aphid species and function as reservoir habitats for parasitoids.

Overall, the study demonstrates that Uttarakhand supports both specialised and broadly polyphagous aphidiine parasitoids, highlighting the ecological importance of the western Himalayan region as a significant centre of aphidiine diversity and natural biological control potential in India. The detailed account of the parasitoids, their aphid hosts and host plant associations are given below:

4.1 *Adialytus ambiguus* (Haliday, 1834)

- ***Melanaphis* sp.**
  - Grass (Das and Chakrabarti, 1989a)

- ***Sipha maydis* Passerini, 1860**
  - *Cynodon dactylon* (L.) Pers. (Chakrabarti and Debnath, 2009)

4.2 *Adialytus salicaphis* (Fitch, 1855)

- ***Chaitophorus* sp.**
  - *Salix caprea* L. (Chakrabarti and Debnath, 2009)

4.3 *Aphidius asteris* Haliday, 1834

- ***Macrosiphoniella kikungshana* Takahashi, 1937**
  - *Artemisia* sp. (Das and Chakrabarti, 1991a)

- ***Macrosiphoniella pseudoartemisiae* Shinji, 1933**
  - *Artemisia vulgaris* L. (Akhtar et al., 2011a)
- ***Macrosiphoniella sanborni* (Gillette, 1908)**
  - *Chrysanthemum* sp. (Raychaudhuri et al., 1982; Chakrabarti and Debnath, 2009)
- ***Macrosiphoniella yomogifoliae* (Shinji, 1922)**
  - *Artemisia* sp. (Chakrabarti et al., 2002; Akhtar et al., 2011a)
- ***Macrosiphoniella* sp.**
  - *Chrysanthemium* sp. (Das and Chakrabarti, 1991a)

4.4 *Aphidius cingulatus* Ruthe, 1859

- ***Macrosiphoniella* sp.**
  - *Populus ciliata* Wall. ex Royle (Sarkar, 2022)
  - *Salix tetrasperma* Roxb. (Sarkar, 2022)
- ***Pterocomma* sp.**
  - *Populus ciliata* Wall. ex Royle (Das and Chakrabarti, 1991a)
  - *Salix tetrasperma* Roxb. (Das and Chakrabarti, 1991a)

4.5 *Aphidius colemani* Viereck, 1912

- ***Aphis nerii* Boyer de Fonsc., 1841**
  - *Calotropis procera* (Aiton) Dryand. (Bisht et al., 2001)
- ***Aphis* sp.**
  - *Rumex* sp. (Das and Chakrabarti, 1990)
- ***Hyalopterus pruni* (Geoffroy, 1762)**
  - *Prunus persica* (L.) Batsch (Das and Chakrabarti, 1990; Das and Chakrabarti, 1991a)
  - *Sorbaria tomentosa* (Lindl.) Rehder (Sarkar, 2022)

4.6 *Aphidius eglanteriae* Haliday, 1834

- ***Capitophorus formosartemisiae* (Takahashi, 1921)**
  - *Artemisia* sp. (Das and Chakrabarti, 1990)
- ***Macrosiphoniella pseudoartemisiae* Shinji, 1933**
  - *Artemisia vulgaris* L. (Das and Chakrabarti, 1990)
- ***Myzus sorbi* Bhattacharya and Chakrabarti, 1982**
  - *Sorbaria tomentosa* (Lindl.) Rehder (Das and Chakrabarti, 1990; Das and Chakrabarti, 2018; arkar, 2022)

4.7 *Aphidius matricariae* Haliday, 1834

- ***Aphis nasturtii* Kaltenbach, 1843**
  - *Datura stramonium* L. (Das and Chakrabarti, 1988; Das and Chakrabarti, 2018)
- ***Brachycaudus helichrysi* (Kaltenbach, 1843)**
  - *Lablab purpureus* (L.) Sweet ssp. *purpureus* (Das and Chakrabarti, 1988; Das and Chakrabarti, 2018)
  - *Prunus amygdalus* Batsch (Das and Chakrabarti, 1990)
  - *Prunus persica* (L.) Batsch (Das and Chakrabarti, 1990)
- ***Capitophorus carduinus* (Walker, 1850)**

- *Cirsium wallichii* DC. (Das and Chakrabarti, 1988; Das and Chakrabarti, 1990)

- ***Lipaphis erysimi* (Kaltenbach, 1843)**
  - *Brassica rapa* L. (Bisht et al., 2001)

- ***Myzus dycei* Carver, 1961**
  - *Urtica dioica* L. (Das and Chakrabarti, 1988; Das and Chakrabarti, 1990)

- ***Myzus persicae* (Sulzer, 1776)**
  - *Lablab purpureus* (L.) Sweet ssp. *purpureus* (Das and Chakrabarti, 1988; Das and Chakrabarti, 1990)

- ***Myzus siegesbeckicola* Strand, 1929**
  - *Urtica dioica* L. (Das and Chakrabarti, 1988; Das and Chakrabarti, 1990)

- ***Phorodon cannabis* Passerini, 1860**
  - *Cannabis sativa* L. (Das and Chakrabarti, 1988; Das and Chakrabarti, 2018)

4.8 *Aphidius polycostulari* Das and Chakrabarti, 1991

- ***Sitobion* sp.**
  - *Rosa* sp. (Das and Chakrabarti, 1991a)

4.9 *Aphidius qadrii* (Shuja-Uddin, 1977)

- ***Brachycaudus* sp.**
  - *Gnaphalium* sp. (Das and Chakrabarti, 1991a)

- ***Capitophorus* sp.**
  - *Anaphalis margaritacea* (L.) Benth. and Hook.f. (Das and Chakrabarti, 1991a)

- ***Myzus ornatus* (Laing, 1932)**
  - Indet (Das and Chakrabarti, 1991a)

- ***Brachycaudus helichrysi* (Kaltenbach, 1843)**
  - *Anaphalis* sp. (Das and Chakrabarti, 1991a)

4.10 *Aphidius rhopalosiphi* de Stefani-Perez, 1902

- ***Sitobion miscanthi* (Takahashi, 1921)**
  - *Triticum aestivum* L. (Das and Chakrabarti, 2018; Sarkar, 2022)

- ***Sitobion rosaeiformis* (Das, 1918)**
  - Grass (Chakrabarti and Debnath, 2009)

- ***Schizaphis* sp.**
  - *Bothriochloa* sp. (Chakrabarti et al., 2002)

4.11 *Aphidius rosae* Haliday, 1833

- ***Macrosiphum rosae* (Linnaeus, 1758)**
  - *Rosa* sp. (Das and Chakrabarti, 2018)

- ***Sitobion rosaeiformis* (Das, 1918)**
  - *Rosa* sp. (Raychaudhuri et al., 1982; Akhtar et al., 2011a)

4.12 *Aphidius smithi* Sharma and Subba Rao, 1959

- ***Acyrthosiphon pisum* (Harris, 1776)**
  - *Pisum sativum* L. (Raychaudhuri et al., 1982)

4.13 *Aphidius staryi* Das and Chakrabarti, 1990

- ***Myzus cornutus* Medda and Chakrabarti, 1986**
  - *Prunus cornuta* (Wall. ex Royle) Steud. (Das and Chakrabarti, 1990; Sarkar, 2022)

4.14 *Aphidius urticae* Haliday, 1834

- ***Acyrthosiphon* sp.**
  - *Euphorbia pilosa* L. (Sarkar, 2022)

4.15 *Aphidius uzbekistanicus* Luzhetzki, 1960

- ***Acyrthosiphon* sp.**
  - *Bothriochloa* sp. (Das and Chakrabarti 1989a)
- ***Schizaphis* sp.**
  - Grass (Das and Chakrabarti, 1989a)
- ***Sitobion miscanthi* (Takahashi, 1921)**
  - *Avena sativa* L. (Akhtar et al., 2011a)
  - *Bothriochloa* sp. (Das and Chakrabarti, 1989a)
  - *Triticum aestivum* L. (Das and Chakrabarti, 1989a; Chakraborty and Chakrabarty, 1994)
- ***Sitobion* sp.**
  - *Cenchrus flaccidus (Griseb.) Morrone* (Das and Chakrabarti, 1989a)

4.16 *Aphidius* spp

- ***Aphis craccivora* Koch, 1854**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)
- ***Aphis farinosa* Gmelin, 1790**
  - *Salix aegyptiaca* L. (Chakrabarti and Debnath, 2009)
- ***Aphis gossypii* Glover, 1877**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)
  - *Psidium guajava* L. (Bisht et al., 2001)
- ***Sitobion rosaeiformis* (Das, 1918)**
  - *Rosa* sp. (Chakrabarti and Debnath, 2009)

4.17 *Archaphidus greenideae* Stary and Schlinger, 1967

- ***Eutrichosiphum* sp.**
  - *Quercus* sp. (Chakrabarti and Debnath, 2009)

4.18 *Betuloxys intermedius* (Shuja- Uddin, 1975)

- ***Capitophorus formosartemisiae* (Takahashi, 1921)**
  - *Artemisia vulgaris* L. (Das and Chakrabarti, 1991a; Das and Chakrabarti, 2018)

4.19 *Betuloxys intermedius* (Shuja- Uddin, 1975)

- ***Capitophorus* sp.**

- *Artemisia vulgaris* L. (Chakrabarti et al., 2002)

- ***Capitophorus* sp.**
  - *Artemisia* sp. (Das and Chakrabarti, 1991a)

4.20 *Binodoxys centaureae* (Haliday, 1833)

- **Indet**
  - *Senecio* sp. (Das and Chakrabarti, 1991a)

- ***Uroleucon* sp.**
  - *Senecio* spp. (Das and Chakrabarti, 1991a)

4.21 *Binodoxys indicus* (Subba Rao and Sharma, 1958)

- ***Aphis craccivora* Koch, 1854**
  - *Solanum nigrum* L. (Akhtar et al., 2011a)

- ***Aphis fabae* Scopoli, 1763**
  - *Solanum nigrum* L. (Das and Chakrabarti, 1990)

- ***Aphis gossypii* Glover, 1877**
  - *Bidens pilosa* L. (Akhtar et al., 2011a)
  - *Capsicum* sp. (Akhtar et al., 2011a)
  - *Cestrum nocturnum* L. (Akhtar et al., 2011a)
  - *Cucumis melo* L. (Shuja-Uddin, 1973)
  - *Hibiscus rosasinensis* L. (Rakhshani et al., 2012)

- ***Aphis* spp.**
  - *Cucurbita* sp. (Das and Chakrabarti, 1990)
  - *Solanum* sp. (Das and Chakrabarti, 1990)
  - *Strobilanthes wallichii* Nees (Das and Chakrabarti, 1990)

- ***Brachycaudus helichrysi* (Kaltenbach, 1843)**
  - *Pyrus* sp. (Das and Chakrabarti, 1990)

- ***Brachycaudus* sp.**
  - *Pyrus* sp. (Das and Chakrabarti, 2018)

4.22 *Binodoxys joshimathensis* (Das and Chakrabarti, 1989)

- ***Sitobion miscanthi* (Takahashi, 1921)**
  - *Bothriochloa* sp. (Das and Chakrabarti, 1989a)
  - *Triticum aestivum* L. (Chakraborty and Chakrabarty, 1994)

4.23 *Binodoxys mackaueri* (Das and Chakrabarti, 1989)

- ***Melanaphis meghalayensis meghalayensis* Raychaudhuri and Banerjee, 1974**
  - *Bambusa* sp. (Das and Chakrabarti, 1989a)

***Binodoxys rubicola* (Shuja- Uddin, 1973)**

- ***Aphis longisetosa* Basu, 1970)**
  - *Rubus ellipticus* Sm. (Das and Chakrabarti, 1991a)

4.24 *Binodoxys sinensis* Mackauer, 1962

- ***Aphis craccivora*** **Koch, 1854**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)

- ***Aphis gossypii*** **Glover, 1877**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)

4.25 ***Binodoxys takecallis*** **(Das and Chakrabarti, 1989)**

- ***Takecallis affinis affinis*** **Ghosh, 1986**
  - *Bambusa* sp. (Das and Chakrabarti, 1989a; Chakrabarti and Debnath, 2009)

4.26 ***Binodoxys tomentosae*** **(Das and Chakrabarti, 1990)**

- ***Myzus sorbi*** **Bhattacharya and Chakrabarti, 1982**
  - *Sorbaria tomentosa* (Lindl.) Rehder (Das and Chakrabarti, 1990)

4.27 ***Cristicaudus garhwalensis*** **Das and Chakrabarti, 1991**

- ***Capitophorus formosartemisiae*** **(Takahashi, 1921)**
  - *Artemisia vestita* Wall ex Besser (Das and Chakrabarti, 1991b; Das and Chakrabarti, 2018)

- ***Capitophorus*** **sp.**
  - *Artemisia vestita* Wall ex Besser (Chakrabarti et al., 2002; Sarkar, 2022)

4.28 ***Cristicaudus indicus*** **Das and Chakrabarti, 1991**

- ***Aphis*** **sp.**
  - *Phyllanthus velutinus* (Wight) Müll.Arg. (Das and Chakrabarti, 1991b)

4.29 ***Diaeretiella rapae*** **(McIntosh, 1855)**

- ***Brachycaudus helichrysi*** **(Kaltenbach, 1843**
  - *Prunus amygdalus* Batsch (Das and Chakrabarti, 1990; Sarkar, 2022)

- ***Brevicoryne brassicae*** **(Linnaeus, 1758)**
  - *Brassica juncea* (L.) Czern. (Das and Chakrabarti, 2018; Verma et al., 2023)
  - *Brassica* sp. (Das and Chakrabarti, 1990)
  - *Raphanus sativus* L. (Bisht et al., 2001; Chakrabarti and Debnath, 2009)

- ***Hayhurstia atriplicis*** **(Linnaeus, 1761)**
  - *Chenopodium album* L. (Das and Chakrabarti, 1990; Das and Chakrabarti, 2018)

- ***Lipaphis (Lipaphis) erysimi*** **(Kaltenbach, 1843)**
  - *Brassica juncea* L. (Verma et al., 2023)
  - *Brassica oleracea* L.var. botrytis (Akhtar et al., 2011a)
  - *Brassica rapa* L. (Kundu et al., 1965; Rafi et al., 2010)
  - *Brassica* sp. (Chakrabarti and Debnath, 2009)

4.30 ***Ephedrus lacertosus*** **(Haliday, 1833)**

- ***Sitobion miscanthi*** **(Takahashi, 1921)**
  - *Bambusa* sp. (Akhtar et al., 2011a)

- ***Takecallis affinis affinis*** **Ghosh, 1986**
  - *Bambusa* sp. (Das and Chakrabarti, 1989a; Sarkar, 2022)

4.31 *Ephedrus laevicollis* (Thomson, 1895)

- ***Cavariella aegopodii* (Scopoli, 1763)**
  - *Salix hastata* L. (Das and Chakrabarti, 1991a)

4.32 *Ephedrus nacheri* Quilis, 1934

- ***Hayhurstia atriplicis* (Linnaeus, 1761)**
  - *Chenopodium album* L. (Das and Chakrabarti, 1990; Das and Chakrabarti, 2018)
- ***Melanaphis* nr. *arundinariae* (Takahashi, 1937)**
  - *Pyrus pashia* Buch.- Ham. ex D. Don (Das and Chakrabarti, 1990)

4.33 *Ephedrus persicae* Froggatt, 1904

- ***Myzus sorbi* Bhattacharya and Chakrabarti, 1982**
  - *Sorbaria tomentosa* (Lindl.) Rehder (Das and Chakrabarti, 1990; Sarkar, 2022)

4.34 *Ephedrus ramnagarensis* Akhtar, 2011

- **Unknown**
  - Unknown (Akhtar et al., 2011)

4.35 *Ephedrus srinagarensis* Stary and Bhagat, 1978

- ***Prociphilus himalayaensis* Chakrabarti, 1976**
  - *Cotoneaster* sp. (Chakrabarti et al., 2002)
  - *Lonicera quinquelocularis* Hardw. (Chakrabarti et al., 2002)
- ***Prociphilus* sp.**
  - *Cotoneaster* sp. (Das and Chakrabarti, 1990)
  - *Lonicera quinquelocularis* Hardw. (Das and Chakrabarti, 1990)

4.36 *Ephedrus* spp.

- ***Aphis* sp.**
  - *Rumex* sp. (Chakrabarti and Debnath, 2009)
- ***Brachycaudus helichrysi* (Kaltenbach, 1843)**
  - *Pyrus pashia* Buch.- Ham. ex D. Don (Chakrabarti and Debnath, 2009)

4.37 *Kashmiria aphidis* Starý and Bhagat, 1978

- ***Prociphilus himalayaensis* Chakrabarti, 1976**
  - *Lonicera quinquelocularis* Hardw. (Chakrabarti and Debnath, 2009; Das and Chakrabarti, 2018)
- ***Prociphilus* sp.**
  - *Lonicera quinquelocularis* Hardw. (Das and Chakrabarti, 1990)

4.38 *Lipolexis oregmae* (Gahan, 1932)

- ***Aphis craccivora* Koch, 1854**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)
- ***Aphis gossypii* Glover, 1877**
  - *Cestrum nocturnum* L. (Chakrabarti and Debnath, 2009)
  - *Rumex* sp. (Das and Chakrabarti, 1991a; Das and Chakrabarti, 2018)

- ***Liosomaphis himalayensis* Basu, 1964**
  - *Berberis* sp. (Das and Chakrabarti, 1991a; Sarkar, 2022)

4.39 *Lysaphidus* sp.

- ***Macrosiphoniella sanborni* (Gillette, 1908)**
  - *Chrysanthemum* sp. (Chakrabarti and Debnath, 2009)

4.40 *Lysiphlebia japonica* (Ashmead, 1906)

- ***Melanaphis sacchari* (Zehntner, 1897)**
  - *Saccharum officinarum* L. (Chakrabarti and Debnath, 2009)

4.41 *Lysiphlebus confusus* Tremblay and Eady, 1978

- ***Aphis* sp.**
  - *Verbascum* sp. (Chakrabarti and Debnath, 2009)

4.42 *Pauesia lachniella* Das and Chakrabarti, 1989

- ***Cinara (Cupressobium) tujafilina* (del Guercio, 1909)**
  - *Thuja* sp. (Bisht et al., 2001)
- ***Lachnus tropicalis* (van der Goot, 1916)**
  - *Lithocarpus dealbatus* Rehder (Das and Chakrabarti, 1989b, 2018)

4.43 *Pauesia orientalis* Das and Chakrabarti, 1989

- ***Cinara maculipes* Hille Ris Lamb., 1966**
  - *Pinus wallichiana A*.B. Jacks. (Das and Chakrabarti, 1989b, 2018; Sarkar, 2022)

4.44 *Praon abjectum* (Haliday, 1833)

- ***Melanaphis donacis* (Passerini, 1862)**
  - *Phragmites* sp. (Chakrabarti and Debnath, 2009)

4.45 *Praon himalayensis* Das and Chakrabarti, 1989

- ***Panaphis juglandis* (Goeze, 1778)**
  - *Juglans regia* L. (Das and Chakrabarti, 1989c; Sarkar, 2022)

4.46 *Praon orientale* Stary and Schlinger, 1967

- ***Uroleucon sonchi* (Linnaeus, 1767)**
  - *Sonchus arvensis* L. (Das and Chakrabarti, 2018)
- ***Uroleucon* sp.**
  - *Sonchus arvensis* L. (Das and Chakrabarti, 1991a; Sarkar, 2022)
  - *Sanchus* sp. (Das and Chakrabarti, 1991a)

4.47 *Praon pubescens* Starý, 1961

- ***Nasonovia* sp.**
  - *Strobilanthes* sp. (Das and Chakrabarti, 1991a; Sarkar, 2022)

4.48 *Praon volucre* (Haliday, 1833)

- ***Macrosiphum* sp.**

- *Rosa* sp. (Das and Chakrabarti, 1991a)

- ***Sitobion* sp.**
  - *Rosa* sp. (Sarkar, 2022)

4.49 *Praon* spp.

- ***Sitobion rosaeiformis* (Das, 1918)**
  - *Rosa* sp. (Bisht et al., 2001)

- ***Uroleucon* sp.**
  - *Sonchus* sp. (Chakrabarti and Debnath, 2009)

4.50 *Toxares* sp.

- ***Shinjia orientalis* (Mordvilko, 1929)**
  - Fern (Das and Chakrabarti, 1991a)

4.51 *Trioxys* spp.

- ***Aphis* sp.**
  - *Rubus* sp. (Chakrabarti and Debnath, 2009)

- ***Capitophorus formosartemisiae* (Takahashi, 1921)**
  - *Artemisia vulgaris* L. (Chakrabarti and Debnath, 2009)

- ***Shinjia orientalis* (Mordvilko, 1929)**
  - Fern (Das and Chakrabarti, 1991a)

5 Conclusion

The present checklist reveals that Uttarakhand supports a rich and ecologically complex assemblage of aphidiine parasitoids, aphids, and host plants, characterised by both highly specialised and broadly polyphagous interactions. The dominance of *Aphidius* species and the extensive associations exhibited by parasitoids such as *Aphidius matricariae*, *Binodoxys indicus*, and *Diaeretiella rapae* highlight their ecological adaptability and potential importance in the natural regulation of aphid populations. At the same time, the occurrence of numerous host-specific parasitoids and aphids reflects the distinct ecological niches and habitat heterogeneity of the Himalayan region. The study also identifies several host plants and crop species that act as important reservoirs of parasitoid diversity and biological control activity. Overall, these findings contribute significantly to the understanding of Himalayan tri-trophic interactions and provide a valuable baseline for future studies on biodiversity conservation, ecological monitoring, and sustainable aphid management in Uttarakhand and adjoining Himalayan ecosystems.

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