Aphids (Hemiptera: Aphididae) in the Himalaya: present status

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Abstract: Aphids, a group of hemipteran obligatory phytophgous insects have distribution throughout the world. Many species are pests of agricultural, horticultural and forest plants and vectors of plant pathogens. The Himalaya, a hot spot zone in India, has many favourable plant species for aphid infestation and many of them are endemic. At present 818 species of aphids with 398 endemic species, in 216 genera and 15 subfamilies, are known from different zones of the Himalaya. There are 76 gall inducing aphid species and these are dominant in Northwest Himalaya. Morphology of many galls is very species specific. Primary and secondary hosts of many species have been explored. Primary host ranges of the gall inducing species are narrow and specific. The Parasitoid and predator complexes are also rich and about 50% parasitoids of aphids here are endemic.

Key words: Diversity, distribution, endemism, host plants, aphid galls, predators and parasitoids.

Aphids are soft-bodied obligatory phytophagous sucking hemipteran pests drawing attention of entomologists throughout the World. Besides mechanical damage to plants, aphids also serve as the largest group of vectors of plant viruses (Eastop 1977, Chan et al. 1991, Ghosh et al. 2017). The damage is further compounded by fouling the host plant with honeydew (Fig. 2) that has an influence on predators and parasitoids. Honeydew also serves as a substrate for growth of fungal complexes that cause sooty mould which on one hand reduces the photosynthetic activity of plants, while on the other hand it reduces plant's aesthetic market value (Miller and Foottit 2009).

Aphids infest different types of plants that are important from the stand point of agriculture, horticulture and forestry. Of the 80 groups of vascular plants in the world only 8 lack aphids, and those groups represent only 3% of the plant species (Eastop 1978). There are little over 5000 valid species of aphids. Among these more than 250 species feeds on agricultural or horticultural crops (Blackman and Eastop 2000). Though this figure represents only approximately 5% of the world aphid fauna, yet the economic consequences of aphid damage are huge (Miller and Foottit 2009). Increased international trade and the consequent increased movement of commodities as well as the intimate relationship between aphids and their hosts have resulted in increased rates of introduction of aphids to different countries (Foottit et al. 2006).

Due to the feeding of aphids several symptoms and abnormalities such as discolouration, stunted growth, curling of leaves are found to occur in different host

plants (Figs. 3-7). Perhaps the most interesting symptom of aphid infestation is the formation of galls on different parts of plant, such as leaf, petiole, leaf base and stem (Figs 8-13). As a result, normal growth and development of the affected parts and also the production of flowers and fruits are hampered and disturbed. So, the total yield of the infested plant is reduced.

It is necessary to explore biodiversity of a particular region to know its local fauna. Many aphid species are oligophagous and/ or polyphagous and have host alternations. They have complicated biology, cyclical parthenogenetic reproduction and life cycle pattern. These insects are also a good model for study in evolutionary biology. Where aphid faunas have been developed, the proportion of adventive species is also high. So exploration for aphid species in different areas from different host plants also helps to identify whether new adventive species has been introduced or not. Aphids, in general, prefer temperate climate. Although some species are cosmopolitan, most of them are restricted to countries of temperate region and/ or found in other countries where some areas have temperate climate.

Of the several mountain systems in India, the Himalayan range is the highest, longest, most wide and vast. The uplift of the Himalaya since late Cenozoic has strongly influenced the environment of this area and surrounding regions as well as the climate in Asia and across the globe (Shi and Li, 1988). In the Himalayan region many plants preferred by the aphids are present and some of them are endemic. This has attracted attention of aphidologists for explorations and studies of aphids here.

This account deals with the present status of aphid taxonomy in the Himalaya. The fauna in different zones of the Himalaya and their endemism have been analyzed. Informations of the aphid galls in the Himalaya, aphid-host plant association, aphid life cycle and the natural enemies of aphids of the Himalaya have also been provided in brief.

1. The Himalaya

The Himalaya is one of the youngest and highest mountain system of the world having life at higher altitudes compared to other mountain systems. The Himalayan range for its Tertiary origin has experienced Pleistocene glaciations and has continuous Post-Pleistocene uplifts (Mani 1974). It maintains its peculiarities, such as enormous massiveness, great elevations of the mountain regions, their trend-lines and their location in the middle of a vast continental mass. The Himalayan range (Fig. 1) extends from Mt. Nanga Parbat to Pamir Knot in the extreme northwest, while with a small curve of about 2500 km length to Namcha Barwa Peak in the east. It lies approximately between east longitude 72^0 and 90^0 and north latitude 27^0 and 37^0.

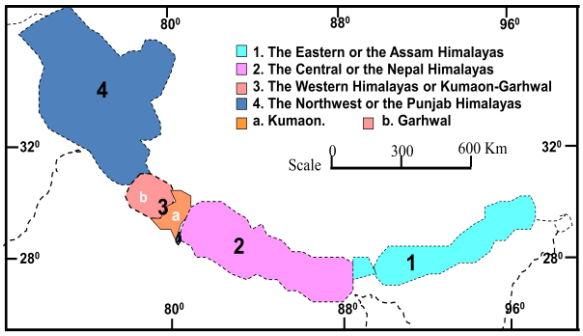
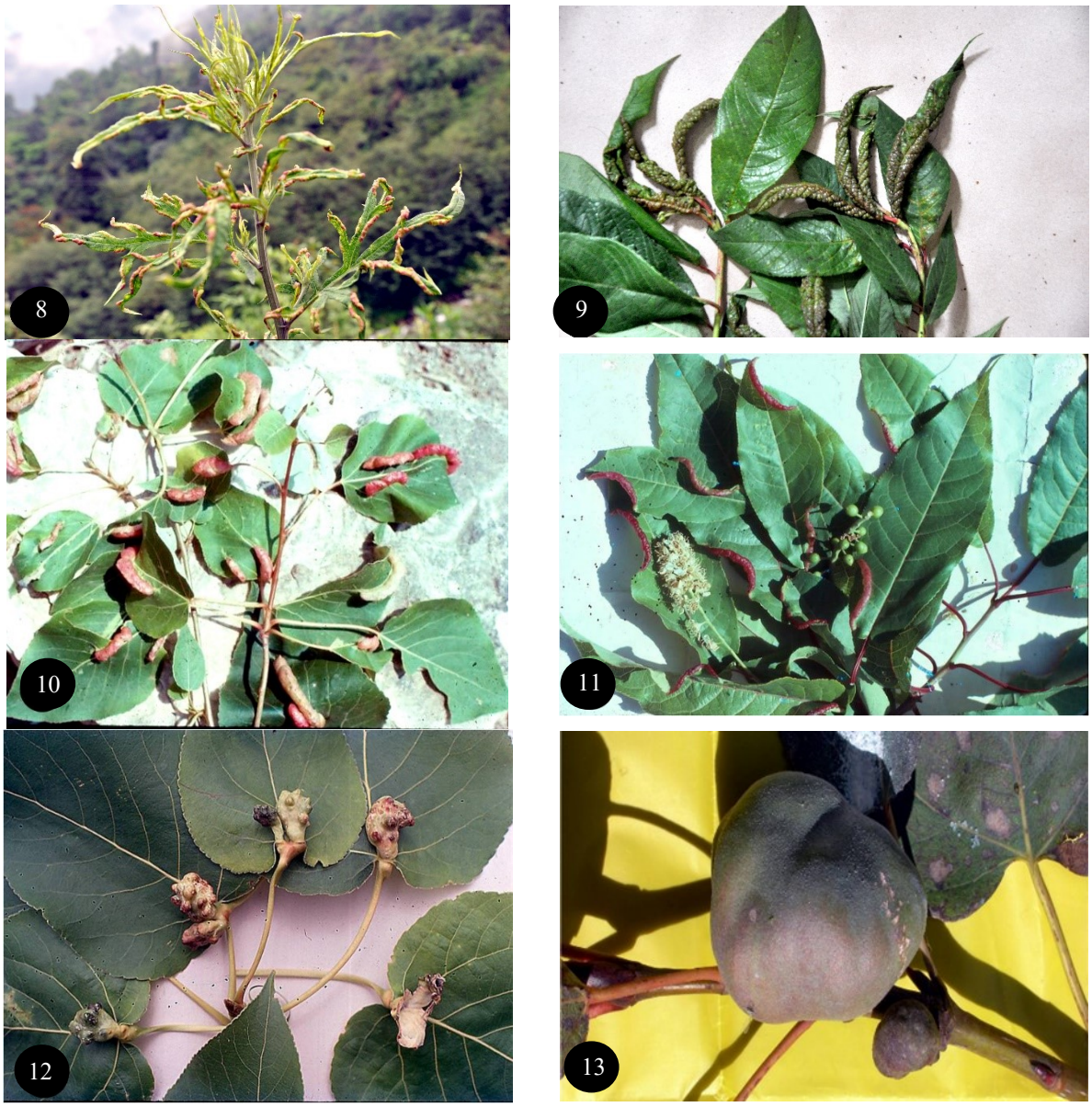


Fig. 1. Different divisions of the Himalaya.

The Himalaya, geo-morphologically as well as traditionally may be demarcated into Eastern Himalaya or Northeast Himalaya, Central Himalaya or Nepal Himalaya and North-west Himalaya. The Central

Figs. 2-7: 2. Honeydew on *Salix alba*; 3. *Sitobion rosaeformis* (Das) on *Rosa* sp.; 4. *Melanaphis sacchari* (Zehtner) on *Saccharum officinarum*; 5. *Cinara tujaphilina* (Del Guercio) on *Platycladus orientalis*; 6. *Mollitrichosiphum* (*Meta*.) *montanum* (v,d.G.) on *Alnus nepalensis*; 7. *Tuberlachnus salignus* (Gmelin) on *Salix alba*.

Himalaya lies between the River Teesta in the east and the River Kali in the west. The major part of the Central Himalaya falls in Nepal. The Royal Kingdom of Bhutan is a part of the Eastern Himalaya. Northwest Himalaya can be demarcated into subzones. Occasionally, the part between the River Kali in the east and the River Sutlej in the west is known as Western Himalaya which is again demarcated into Kumaon in the east and Garhwal ranges in the west. The rest of the Northwest Himalaya west of the River Sutlej up to Indus valley falls in Himachal Pradesh and Jammu and Kashmir in India. The extreme west portion of Northwest Himalaya beyond Indus valley up to Nanga Parbat is now within Pakistan and identified as Pakistan Himalaya (Mani, 1974).



Figs. 8-13. 8. Leaf marginal galls of *Cryptosiphum artemisiae* Buckton on *Artemisia vulgaris*; 9. Leaf- curl galls of *Brachycaudus helichrysi* (Kaltb.) on *Prunus persica*; 10. Leaf caterpillar galls of *Epipemphigus imaicus* (Chold.) on *Populus ciliate*; 11. Leaf marginal galls of *Eumyzus pruni* Chakrabarti and Bhattacharya on *Prunus cornuta*; 12. Leaf base gall of *Pemphugus matsumurai* Monzen on *Populus ciliate*; 13. Stem galls of *Pemphigus mordvilkoi* Chold. on *Populus ciliate.*

Himalaya is also unique; the Eastern Himalaya is very rich floristically and is influenced by Sino-Japanese (Manchurian), Indo-Chinese and Malayan flora while the Northwest Himalaya is influenced by the Eurasian and Mediteraian flora (Rao, 1994). The Himalaya exhibits the terai, subtropical, temperate and alpine vegetations with the change of altitudes. Both Eastern and Northwest Himalaya have many endemic floras that have enormous influence on the prevalence, distribution and biology of

aphids. Vegetations in the Himalaya are also influenced by the difference in rainfall and mountain slopes.

2. Historical perspectives

Buckton (1893) described *Oregma bambusae* (= *Astegopteryx bambusae*) from Dehradun, a foothill city of the Himalaya and later in 1896 he described *Pemphigus immunis* from Gilgit, Kashmir and *Pemphigus napeaus* from Darkot Pass, Kashmir. Cholodkovsky (1912) described three new species viz. *Pemphigus imaicus* (= *Epipemphigus imaicus*), *Pemphigus mordvilkoi* and *Pemphigus nainitalensis* from the Kumaon range of the Northwest Himalaya. Das (1918) (published posthumously by P. van der Goot) provided an excellent account of 40 species in 18 genera of aphids from Lahore, now in Pakistan which is actually situated in the Upper Indus valley. Aphid studies in the Himalaya got momentum since the Sixties of the last Century when a number of workers started exploring aphids particularly in Eastern and Northwest Himalaya [details documented in Ghosh (1974), Raychaudhuri (1980), Chakrabarti (2015)]. Other than the above accounts, reports of aphids from the Kingdom of Bhutan (a part of Eastern Himalaya: Chakrabarti et al. 2020 and personal data) and from Nepal (Central Himalaya: Das and Raychaudhuri, 1988) are worth mentioning. Aphids from Pakistan (Northwest Himalaya) were listed by Naumann-Etienne and Remaudiere (1995). Later, Remaudiere (2002), and Remaudiere and Binazzi (2003a, 2003b) and Kanturski et al. (2017) added several species to this list from here.

3. Methodology

Aphids are in general, collected directly from the plant surface using hand with the help of a soft camel-hair brush and preserved within 70-80% ethyl alcohol in ependrop vials or glass tubes with good stoppers. Associated predators, parasitoids and scavengers are also collected from the aphid colonies and preserved suitably. Rearing of immature of aphids and associated predators and parasitoids was performed for obtaining adult individuals, if required. Yellow Pan Traps (YPT) are employed, where possible, for collecting flying aphids.

Field records such as site of infestation, symptoms on the host plant, colour of aphid, colour of individual body part of the live specimen, habitat, associated organisms, their roles, population size, presence of wax on body etc. are also noted at the collection sites. The name of the host plant is to be noted. If it is not possible to identify at the site, sufficient plant parts should be collected to prepare herbarium for future identification. Field photographs of both aphids and their host plants are taken. Aphid samples after processing in KOH and subsequently passing through grades of ethyl alcohols, are finally mounted in Canada balsam. The prepared specimens are stored and arranged according to classificatory categories.

4. Results and Discussions

4.1 Aphid diversity

The Himalaya has very rich aphid diversity. So far, 818 species in 216 genera and 15 subfamilies (Table 1) have been reported from this mountain system and its foothills. Only 25 aphid species and 4 genera found in other areas of the Indian subregion (eg Peninsular, Gangetic plains and Indus valley) are missing in the Himalaya. Thus,

the Himalaya comprises of 16.36% of the world aphid species and 97.14% of the total species found in the Indian subregion. The subfamily Aphidinae has 468 species (57.09% of the total species) in 111 genera and thus this is the most dominating subfamily in this area. Next to Aphidinae there come Greenideinae (85 species), Eriosomatinae (62 species), Lachninae (44 species), Hormaphidinae (52 species) and Calaphidinae (50 species), respectively. The number of species in different genera of the respective subfamilies have been provided in Table 1.

In spite of presence of same or similar host plants in some localities, the distribution of aphids is not homogeneous throughout the Himalaya. Eastern Himalaya (including Bhutan) has 481 species in 148 genera. Bhutan alone has 91 species in 55 genera. In Central Himalaya or Nepal Himalaya there are only 60 species in 27 genera known so far. While in Northwest Himalaya (including area falling in Pakistan) has 542 species in 177 genera. In the Northwest Himalaya within Pakistan 269 species in 107 genera have also been recorded. The aphid fauna reported from the different parts of the Northwest Himalaya such as, Kumaon-Garhwal, Himachal and Jammu and Kashmir zones also differ from each other. However, faunistic explorations and systematic studies are not uniform in all the parts of the Himalaya. The number of genera and species occurring in different subfamilies in these areas are given in Table 1.

The Central Himalaya has been explored lesser for aphid fauna compared to that in the Eastern and the Northwest Himalaya. The under mentioned 7 new species viz., *Aiceona himalaica* Miyazaki, *Aiceona parvicornis* Miyazaki (Anoecinae), *Dysaphis sharmai* Stroyan, *Dysaphis ramani* Das and Raychaudhuri, *Sinomegura nepalensis* Das and Raychaudhuri (Aphidinae), *Panaphis nepalensis* Quednau (Calaphidinae), and *Cinara saraswati* Das and Raychaudhuri (Lachninae) described from here are still reported only from this area and exclusively endemic till today (Table 2). *Prociphilus cornifoliae* Singh et al. (Eriosomatinae) which was described from here is also found in Manipur. Of the 60 species known from the Central Himalaya, 36 species are common to both Eastern and Northwest Himalaya. Rest of the 24 species (Table 2) are not evenly distributed, although 13 of the above species are endemic to the Himalaya. Only, 11 of the above 24 species are found in the Eastern Himalaya and only 2 species, *Diuraphis noxia* (Kurdjumav) and *Cinara tenuepes* Chakrabarti and Ghosh have been reported from the Northwest Himalaya. Space and time will not permit to discuss and describe the distribution and common occurrence of each and every species in different regions or divisions of the Himalaya. Table 1 shows that 542 species in 177 genera are found in Northwest Himalaya. Of these species, 74 species occur exclusively in this area west of the Indus River which is now in Pakistan. Among the species that are found in the Eastern and Northwest Himalaya, 210 species are common in both zones. It is further interesting to mention that at least 82 species are common between the Himalaya and the Qinghai-Tibetan Plateau.

The diversity of species in many genera is not homogenous in Northwest and Eastern Himalaya. Representatives of several

Table 1. Distribution of genera and species including endemic species in different zones of the Himalaya.

	Himalaya		Eastern Himalaya		Central Himalaya		NW Himalaya		Pakistan Himalaya		Common species of Eastern & NW Himalaya
Subfamily	**Genera/ species**	**Endemic**	**Genera/ species**	**Endemic species**	**Genera/ species**	**Endemic species**	**Genera/ species**	**Endemic species**	**Genera/ species**	**Endemic species**	
Aiceoninae	1/9	9	1/7	7	1/2	2	1/2	2	x	x	2
Anoeciinae	1/6	2	1/4	1	x	x	1/5	1	1/2	x	3
Aphidinae	111/467	209	75/265	109	6/22	x	105/348	147	63/177	29	143
Calaphidinae	22/50	29	14/30	21	6/6	1	18/31	18	11/17	7	13
Chaitophorinae	5/28	13	4/7	4	x	x	5/26	10	4/15	6	5
Drepanosiphinae	2/4	2	1/1	1	x	x	2/3	1	1/1	x	x
Eriosomatinae	19/62	31	12/27	14	3/3	x	16/47	20	13/29	11	13
Greenideinae	9/85	59	8/73	54	3/14	6	4/24	16	3/4	x	16
Hormaphidinae	24/52	21	19/40	17	4/6	1	11/18	5	2/2	1	5
Lachninae	15/44	19	10/23	7	4/7	2	10/31	14	6/18	12	10
Minadarinae	1/2	x	x	x	x	x	1/2	x	1/1	x	x
Phloeomyzinae	1/1	x	x	x	x	x	1/1	x	1/1	x	x
Phyllaphidinae	2/2	1	2/2	1	x	x	x	x	x	x	x
Saltusaphidinae	1/2	x	x	x	x	x	1/2	x	1/2	x	x
Thelaxidinae	2/4	3	1/2	1	x	x	1/2	2			x
Total	216/818	398	148/481	237	27/60	12	177/542	236	107/269	66	210

Table 2. Aphid species in Central Himalaya not found in all other zones of the Himalaya.

	Aphid species	Eastern Himalaya	Northwest Himalaya	Endemic in the Himalaya	Endemic in Nepal
	Anoecinae				
1.	*Aiceona himalaica* Miyazaki				Y
2	*Aiceona parvicornis* MIyazaki				Y
	Aphidinae				
3.	*Aphis glycines* Matsumura				
4.	*Aphis hardyi* Eastop				
5.	*Diuraphis noxia* (Kurdjumav)				
6.	*Dysaphis ramani* Das and Raychaudhuri				Y
7.	*Dysaphis sharmai* Stroyan				Y
8.	*Macrosiphoniella spinipes* Basu		P	Y	
9.	*Sinomegoura simplocosis* (VDG)				
10.	*Sinomegoura nepalensis* Das and Raychaudhuri				Y
11.	*Vesiculaphis caricis* (Fullaway)				
	Calaphidinae				
12.	*Panaphis nepalensis* Quednau				Y
	Eriosomatinae				
13.	*Prociphilus cornifoliae* Singh et al.		P	Y	
	Greeneidinae				
14.	*Eutrichosiphum passanae* (Okajima)				
15.	*Eutrichosiphum quercifoli* Ghosh et al.	P		Y	
16.	*Greenidea longicornis* Ghosh et al.	P		Y	
17	*Greenidea photiniphaga* Raychaudhuri et al.	P		Y	
18.	*Sumatraphis celti* Takahashi	P			
	Hormaphidinae				
19	*Ceratovacuna indica* Ghosh et al.	P		Y	
20.	*Pseudoregma alexandri* (Takahashi)	P			

21.	*Schizoneuraphis querciphaga* (Ghosh and Raychaudhuri)	P	Y	
	Lachninae			
22.	*Cinara saraswati* Das and Raychaudhuri			Y
23.	*Cinara tenuipes* Chakrabarti and Ghosh	P	Y	
24.	*Nippolachnus querciphaga* Ghosh and Raychaudhuri	P	Y	

P= Present. Y= Yes

genera missing in a particular area have been depicted in Table 3. Northwest Himalaya is unique with the representatives of several genera of Aphidinae, Eriosomatinae, Hormaphidinae, Phloemyz--inae, Saltusaphidinae and Thelaxinae, while its Eastern counterpart has interesting species of the genera belonging to Greenideinae, Hormaphidinae, Lachninae and Phyllaphidinae. Species diversity also varies in many genera between these two regions.

4.2 Endemic fauna

The Himalaya is the abode of many endemic plants. It also represents a high percentage of endemic aphid fauna as is found in many other groups of insects (Mani, 1974). As many as 398 species of aphid (48.65%) are endemic to the Himalaya. The distribution of endemic species in different subfamilies of aphids in different divisions of the Himalaya is presented in Table 1. Endemic species number also varies in different subfamilies. For example, all the 9 species of the genus *Aiceona* (Aiceoninae) found in the Himalaya are endemic. In Eastern Himalaya 7 species are found of which only 2 species are common with the Kumaon-Garhwal range of Northwest Himalaya. *Aiceona himalaica* Miyazaki and *Aiceona parvicornis* Miyazaki are restricted to the Central Himalaya only. No representative of *Aiceona* has been recorded so far from Bhutan, a part of the Eastern Himalaya. In the Himalaya, 69% of species of Greenideinae, 58% Calaphidinae, 51.85% Lachninae, 50% Eriosomatinae, 45% Aphidinae, and 40% Hormaphidinae are endemic. It has been noted that many such endemic species have restricted distribution even within the Himalaya. However, the subfamilies Minadinae, Phloeomyzinae and Saltusaphidinae have no endemic species in the Himalaya. Altogether 236 endemic species (43.54%) occur in Northwest Himalaya while 239 endemic species (49.27%) are found in Eastern Himalaya. Discussion on the distribution of the endemic species and their association with the host plants in the Himalaya is an interesting topic in aphid- plant association and evolution of aphids.

Endemism has a correlation with age and isolation of an area, and also with the diversification of its habitat. Such factors have a direct influence in the evolution resulting in the speciation of endemic forms as well as the preservation and survival of relic endemics (Kruckeberg and Rabinowitz, 1985). Endemism is influenced by the

Table 3. Representative of species of some genera missing in Northwest and Eastern Himalaya.

Northwest Himalaya	Eastern Himalaya (including Central Himalaya)
Aphidinae *Akkaia, Brachysiohoniella, Kaochiajoa, Scleromyzus, Taiwanamyzus*	*Aphidura, Aspidophorodon, Brachyunguis, Chaitaphis, Cryptaphis, Chakrabartiella, Longicaudus, Eichinaphis, Ephedraphis, Eucarazzia, Myzaphis, Nasonovia, Neotoxoptera, Nudisiphon, Obtusicauda, Spinaphis, Tumoranuraphis, Wahlgreniella, Xerobion*
Eriosomatinae: *Chaetogeoica, Formosaphis*	*Baizongia, Kaburagia, Salvum, Thecabius, Gharesia, Kaltenbachiella, Schizoneurella*
Greenideinae: *Allotrichosiphum, Anomolosiphum, Cervaphis, Greenidedoidea, Sumatraphis*	
Hormaphidinae: *Euthoracaphis, Glyphinaphis, Heminipponaphis, Indonipponaphis, Machilaphis, Metanipponaphis, Parathoracaphis, Schizoneuraphis, Sinonipponaphis, Thoracaphis, Tuberaphis*	*Aleurodaphis, Doraphis, Hamamelistes, Pseudessogella*
Lachninae: *Eulachnus, Sinolachnus*	
Other subfamilies *Kurisakia, Taiwanaphis*	*Mindarus, Phloemyzus, Saltusaphis, Neothelaxes.*

geographic area, ecological breadth and isolation (Carlguist, 1974). Since aphids are obligate plant parasites, to study the distribution of endemic fauna in the Himalaya its unique microclimatic factors as well as the altitudinal variation in distribution of host plants should be taken into account (Chakrabarti, 2009).

5.3 Aphids as gall inducers in the Himalaya

Galls include a variety of structural abnormalities or deformations ranging from simple curling, folding and rolling to complex deformities with definite shape and size displaying distinct tissue differenciation (Mani, 1964). Among arthropods, some insect taxa of the order Diptera, Hymenoptera, Hemiptera, Thysanoptera, Lepidoptera and Coleoptera, and some mite taxa, Eriophyoidea and Tenuipalpidae induce galls on their host plants. Hemipteran galls are of open type and induced by some members of Aphidoidea, Psylloidea and Coccoidea. In the superfamily Aphidoidea some species of aphids and majority of adelgid and phylloxerid species can induce galls on their host plants.

Aphid are specialist gall inducer. They stand next to Cecidomyiidae (Diptera) and Eriophyoidea (Acari) and Cynipoidea (Hymenoptera). Not all aphid species induce galls on their primary host plants. Nevertheless, a gall inducing aphid species cannot induce galls in all stages of their life. In aphids, the first instar fundatrices (developing from hibernating eggs) can only induce galls on specific host plants (primary host) at a specific period (time) and at a specific site. Other subsequent morphs and individuals may help in increasing the size of the gall but are unable to initiate a new gall. If a fundatrix is released on its secondary host plant it cannot initiate a gall. Only 10-20% of the total aphid species of the world are known as gall inducer (Remaudiere and Remaudiere, 1997).

In spite of rich aphid diversity in India, particularly in the Himalaya, only 76 species have so far been found to induce galls on their host plants. Chakrabarti (2001) has provided a list of such species. These species are restricted to only 4 subfamilies *viz.,* Aphidinae, Calaphidinae, Eriosomat--inae and Hormaphidinae. All these species are known from the Himalaya. Table 4 depicts the distribution of 76 gall aphid species in different zones of the Himalaya.

It is worthy to mention that the species of the subfamilies Greenideinae and Hormaphidinae are mostly distributed in East and South-east Asia including India and infest many tree species. Galls have never been found induced by any greenedeine aphids anywhere. Gall inducing hormaphidine aphid species are also least known from India although many gall inducing species of this group have been reported from other countries. This may be due to the fact that most of the species of hormaphidine aphids in India have been collected from their secondary hosts only. The plant genera viz., *Distylium* and *Styrax* are the principal primary hosts of many genera of hormaphidine aphids but these have not been surveyed properly. Several species of the above two plant genera are found in Khasi Hills in Meghalya and also in other northeast Indian states, in addition to Bhutan and Myanmar (Brandis, 1906). If properly flora of these regions would be explored, the primary hosts and galls of many hormaphidine aphids may be found out.

5.4 Aphid gall morphology

Aphid induced galls are cataplasmic (irregular growth i.e., leaf-fold, leaf-roll, leaf-spiral, leaf pouch etc) or prosoplasmic growth (with a definite shape, colour, duration of gall phase/ stage and orientation which are specific for each species). Aphid galls are open type. The galls induced by

Table 4. Number of gall inducing aphid species in the different zones of the Himalaya.

Family/Tribe	Total species	Endemic species	Kumaon-Garhwal	Himachal-Jammu Kashmir	Pak	Eastern	Central
Aphidinae	31	16	31	13	14	8	5
Eriosomatinae							
Eriosomatini	13	3	12	5	9	1	1
Fordini	6	1	6	1	3	2	-
Pemphigini	20	11	17	6	6	1	-
Calaphidinae	2	2	2	1	-	1	-
Hormaphidinae	3	-	2	1	-	-	-
Total	76	33	70	27	32	13	1

Pak= Pakistan part of the NW Himalaya, Eastern= Eastern Himalaya, Central= Central Himalaya

the species in Aphidinae (Figs 8, 9, 11) and Calaphidinae are all cataplasmic in nature. Though some galls in subfamilies Eriosomatinae and Hormaphidinae are cataplasmic, yet majority of them are prosoplasmic (Figs 10, 12, 13). The galls are induced on different parts of leaves or stems. Even when on the same plant species several such galls are induced by different aphids, these may be distinguished from each other by the morphology and other biological characteristics of the galls. For example, as many as 12 different species of aphids induce galls on leaf base, petioles, lamina and stems of *Populus ciliata* (Figs 10, 12, 13) but these are distinctly different and the aphid species can be identified even in the field on the basis of gall morphology. Similar different types of galls are also induced on plant species in the genera like *Hydrangea*, *Prunus, Pistacea* and *Ulmus.*

Although the gall morphology of one aphid is specific, there are a few examples where a particular aphid may induce two different types of galls (dimorphic). *Prociphilus himalayensis* Chakrabarti induces 'leaf-curl galls' initially when leaves are very young and later it induces 'leaf-fold galls' when leaves are quite mature (Banerjee and Chakrabarti, 1993). Similarly, *Eumyzus prunicolus* Medda and Chakrabarti induces 'leaf-curl galls' initially and later a different type of 'leaf-caterpillar' galls ((Medda and Chakrabarti, 1986).

5.5 Aphids and plant association in the Himalaya

Aphids being obligatory phytophagous develop intimate relation with their host

Table 5. Host association of different genera of Eriosomatine aphids in the Himalaya.

Aphid tribe/ genera	Primary host plant	Secondary host plant
Fordini	-	-
Forda	*Pistacea* spp.	Poaceae
Geoica	*Pistacea* spp.	Poaceae
Baizongia	*Pistacea* spp	Poaceae
Pemphigini	-	-
Epipemphigus	*Populus* spp.	*Polygonaceae*
Pemphigus	*Populus* spp.	Different dicotyledons
Prociphilus	*Caprifoliaceae, Oleaceae*	Conifers
Thecabius	*Populus* spp	*Rananculus* spp., *Salix* spp.,
Eriosomatini	-	-
Eriosoma	*Ulmus* spp.	Pyroidea, Rosaceae Grossullariaceae
Kaltenbachiella	*Ulmus* spp.	Lamiaceae, Polygonaceae
Tetraneura	*Ulmus* spp	Poaceae

plants. They are good plant taxonomists (Eastop 1978) and can select specific host plant. Host association is correlated with their life cycle and cyclical parthenogenetic reproduction (Chakrabarti 2007). Many aphids alternate between woody primary and herbaceous secondary host plants improving the exploitation of favourable food resource in different seasons of the year. The ability to utilize two different plants thus plays an important role in selecting the fitness of a species (Mackenzie and Dixon 1991).

Only few studies on host specific aphid studies have been conducted in the Himalaya. Chakrabarti and Banerjee (1993) provided an account of host associations of heteroecious aphids in Northwest Himalaya. Host associations in gall aphids, particularly primary hosts association, are very specific and restricted. Host plant catalogues of Indian aphids are available (Raychaudhuri, 1983, Chakrabarti and Sarkar 2001). Chakrabarti (2007) has provided accounts of host association in gall inducing aphids in the Himalaya. Host associations with primary and secondary hosts in some genera of gall inducing eriosomatines aphids are provided in Table 5.

5.6 Life cycle of aphids

Host alternation is an ancestral feature in aphid biology with woody plant as primary host and herbaceous plants as secondary hosts. Aphids produce different morphs (polymorphism) on these plants. Evolution of different types of life cycles such as loss of host alternation, loss of primary host, loss of secondary host, suppression of some morphs including sexual cycles, acquisition of new host plants are endless complexities of variations (Moran, 1992; Wool, 2004; Chakrabarti, 2007). The type of life cycle is closely related to the behavoiur of that species whether it is either autoecious (non-host alternating) or heteroceous (host-alternating) and reproductive pattern i.e. parthenogenetic (anholocyclic) or cyclical parthenogenetic (holocyclic). When these two phenomena combine in the life of

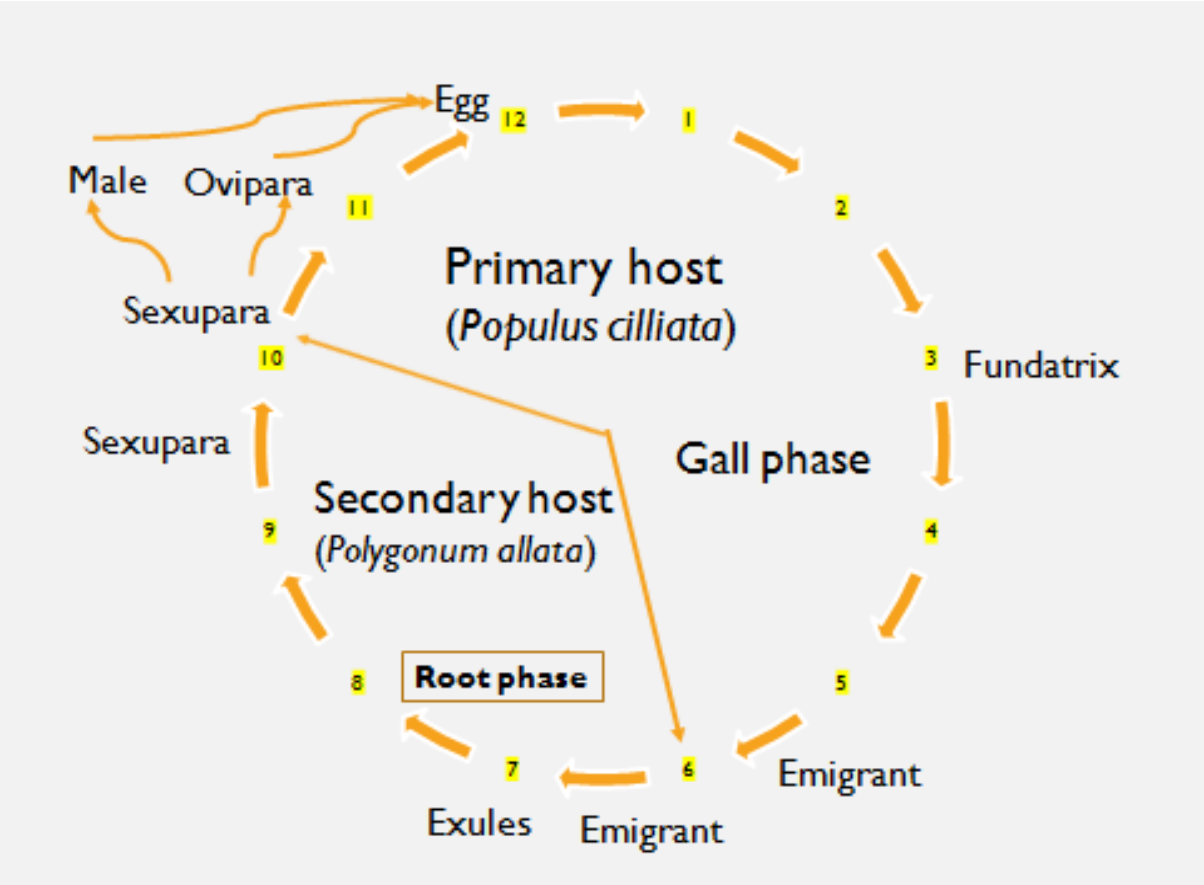


Fig. 14. Heteroecious holocyclic life cycle of *Epipemphigus imacus* (Chlod.) in Joshimath, Uttarakhand (Numbers in the figure designate months).

aphids, the biology and and life cycle become complex.

Very little work has been conducted on the biology and life cycle of aphids in the Himalaya. Studies on the biology and life cycle of *Brachycaudus helichrysi* (Kaltenbach), *Eriosoma lanigerum* (Hausmann) and *Myzus persicae* (Sulzer) in the Himalaya were conducted only on one host. So far, biology and life cycle of only two host alternating aphid species in the Himalaya, *Epipemphigus imaicus* (Cholod.) and *Prociphilus himalayensi*s Chakrabarti were studied in Joshimath, Uttaranchal and their both hosts were confirmed through conducting host transfer experiments (Banerjee and Chakrabarti, 1993; Chakrabarti and Banerjee, 1993). The life cycle pattern of *E. imaicus* is presented in Fig. 14. Different modifications in the life cycle pattern, particularly in gall inducing aphids have been observed during field collections and detailed study on their biology may provide many more informations.

5.7. Parasitoids

Parasitoids of aphids are mainly belonging to hymenoptern families Braconidae and Aphelinidae. Rao (1969) made systematic bio-ecological studies on parasitoids during 1964 to 1969 primarily on five aphid

species, *Acyrthosipon pisum* (Harris), *Aphis gossypii* Glover, *Brevicoryne brassicae* (Linn.), *Lipaphis erysimi* (Kaltenbach) and *Longiunguis* (=*Melanaphis*) *sacchari* (Zehntner). Besides recording several aphidiid parasitoids on the above aphids, he found 2 aphelinids. Bhagat (1980) gave an account of 53 species in 13 genera including 11 new species mainly from Kashmir in Northwest Himalaya. He further recorded 11 hyperparasitoids from these primary parasitoids. Stary and Ghosh (1983) provided accounts of 72 species in 25 genera of aphidiids from the India. Raychaudhuri (1990) gave a historical account of aphid parasitoid studies in India and mentioned about 122 species of aphidiid parasitoids in 20 genera from more than 100 aphid species occurring in India and has provided details of 87 species in 17 genera that occur in Northeast India. Das (1988) explored parasitoids of aphids in the Garhwal range of Northwest Himalaya, recorded 34 species in 14 genera including 10 new species and studied bio-ecology of 2 species, *Aphidius matricariae* Haliday and *Kashmria aphidis* Stary and Bhagat. Chakrabarti and Debnath (2009) mentioned about 114 aphidiid and 2 aphelinid parasitoids on about 175 aphid species in Northwest Himalaya and mentioned that 50 aphidiid parasitoids are endemic in the Himalaya. Das and Chakrabarti (2018) gave an account of bio-ecology of 11 species of hyperparasitoids in 8 genera of 5 hymenopteran families on aphid parasitoids from the Garhwal ranag of Northwest Himalaya.

5.8 Predators

Predators of aphids mainly belong to the order Coleoptera (Chysomelidae, Coccinelidae), Diptera (Syrphidae, Cecidomyiidae), Hemiptera (Anthocoreidae) and Neuroptera (Chrysopidae and Hemerobiidae). In addition, several spiders and few lepidipteran larvae ((Lycaenidae) are of minor importance. However, most of the works on aphid predators in the Himalaya are restricted to the exploration of different groups of predators and feeding potentialities of one or a few species of coccinellids, syrphyids and neuropterans. Debnath (1991) recorded 25 coccinellid, 8 anthocoreid, 10 chrysopid, 2 hemerobiid, 14 syrphyid, 1 chaemaemyiid and 14 spiders from Garhwal range of Northwest Himalaya and studied the bio-ecology of some of them. Chakrabarti et al (2012) provided accounts of 78 species of coccinellids, 13 species of syrphyids, 4 species of chysomelids and 2 species of lycaenids feeding on 122 aphid species in Eastern Himalaya and North-east India.

6. Conclusion

The Himalaya is a biodiversity hot spot, rich in various insect and plant species. Aphids here, represent about 16.5% of the world aphid fauna. Many areas and localities have not been explored yet. Further surveys will add many more species to the present data. The taxonomical history of Aphidoidea indicates that extensive works on the development of stable classification systems up to generic and specific levels are necessary at present. Analysis of data, enriched with more and more species would help to investigate the introduction, migration and establishment of new species, more and more precisely. This is true particularly for adventive species. Such surveys need an awareness of flora also, as lives of aphids depend on plant types. Studies on biology and life cycles of aphids

are neglected fields. Elaborate knowledge on these fields at infraspecific level will throw light on many taxonomic problems of this polymorphic parthenogenetic species group. Since management of aphids using natural enemies is advocated throughout the world, serious attention should also be paid to the exploration and utilization of parasitoids and predators. Molecular taxonomy of aphids is another important field to be explored thoroughly. People need correct and immediate identification of pests as well as their natural enemies. Such informations as discussed above may strengthen the correct identification of an aphid species.

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