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BIOGEOGRAPHICAL CONSIDERATIONS OF INDIAN APHIDIDAE (HOMOPTERA)

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Abstract

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Biogeographical peculiarities of ecological subunits of India are discussed in regard to the abundance, endemism, polyphagism and host plant association of aphids.

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INTRODUCTION

In the Oriental Region India occupies an interesting topography. Biogeographically India can be distinguished into five regions, namely, Northeast Region, Northwest Region, Peninsular Region, Gangetic Plains and Indus Plains (Fig. 1). Physiography, climate and vegetation of these regions are diverse and characteristic, and each of these regions may be regarded as an ecological subunit. In the south the country is peninsular, while on east and west sides it is contiguous with landmasses of entirely different kinds; in the north, vast north-south stretch of Himalaya overrides the adjoining countries. The biogeographical diversity of India is well reflected in the distribution and abundance of flora and fauna, and aphid-host plant association is a typical example. Relative abundance, endemism, polyphagism and host plant association of aphids are characteristic of each region. The Himalayan areas of Northeast and Northwest Regions are richer than the Peninsular Region in vegetation and aphid fauna. Gangetic and Indus Plains are relatively very poor in flora and aphid fauna.

In spite of the vast differences in floral distribution and aphid faunal composition in different biogeographical regions of India there has been no attempt to analyse the biogeographical peculiarities of the five regions in respect of abundance of aphids, endemism in different regions, polyphagism and host plant association. Most of the

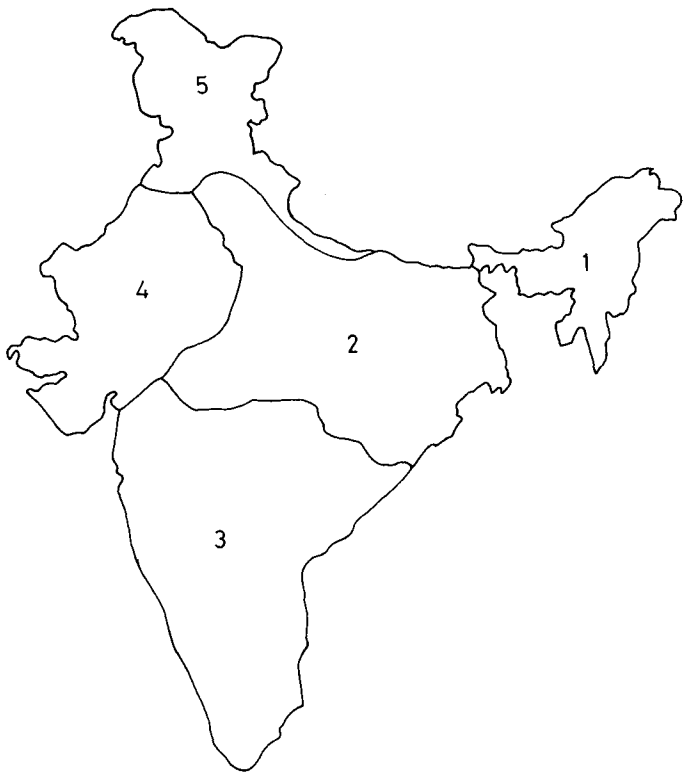

Fig. 1. Map of India showing five biogeographical regions: 1-NE India, 2-Gangetic Plains, 3-Peninsular India, 4-Indus Plains, 5-NW India.

Indian works on aphids relate to taxonomic studies based on sporadic collections from different regions. Several workers, independently or in groups, were involved in such study and most of their findings were discrete results confined to scattered publications except for the recent consolidated taxonomic accounts produced by Raychaudhuri (1980) and Ghosh (1980 and 1982), and Checklist of Indian Aphidoidea prepared by Agarwala and Ghosh (1984). A major breakthrough in the understanding of aphid relationship with the biogeographical peculiarities of India was achieved through the Indo-Japanese collaborative expeditions of entomologists, which provided an opportunity for the undertaking of extensive exploration of agricultural and forest insects including aphids. Both the authors participated in the expeditions in part on behalf of the University of Calcutta. This presentation owes much of its contribution to the said collaborative programme. This paper has considered the published works on Indian Aphididae till June 1982 and incorporates the experience of field observations of both the authors for the last several years. Indian Aphididae comprise 645 species belonging to 202 genera under seven subfamilies with endemism estimated at 55.66% and polyphagism as high as 400 plant species in the case of *Aphis gossypii* Glover. Information on host plants and aphid species has mainly been drawn from two recently prepared manuscripts: Food Plant Catalogue of Indian Aphididae (ed. Raychaudhuri, 1983) and A Checklist of Aphidoidea of India (Agarwala and Ghosh, A.K., 1984), and, therefore, these two publications may be considered as important appendices to this paper.

Abundance of aphids

The distribution of 645 species of aphids included in 202 genera and seven subfamilies shows remarkable regional variation not only numerically but also with respect to species. Maximum number of 397 species have so far been recorded from Northeast India. This is closely followed in Northwest India where 342 species have been recorded. In Peninsular India there occur 115 species, being one-sixth of the total number of aphid species found in India. In the remaining two regions the number of species recorded is too meagre; that is, 67 in the Gangetic Plains and only 27 in the Indus Plains.

Out of 202 genera recorded in India, Northeast India accounts for 157. This is followed by Northwest India where 126 aphid genera have been recorded. In Peninsular India 58 genera are on the record while from Gangetic Plains and Indus Plains 32 and 14 genera respectively have been recorded. It is interesting to note that genera belonging to all the seven subfamilies are present only in Northeast and Northwest India. In Peninsular India subfamily Anoeciinae has not been recorded so far and from Gangetic Plains members of Lachninae are also absent. From Indus Plains only members of subfamilies Aphidinae, Callipterinae and Pemphiginae could be recorded. Another interesting feature of generic distribution is in the presence of genera belonging to subfamilies Aphidinae and Callipterinae in all the regions of India and the domination of the genera of subfamily Aphidinae in all the five regions over the genera of other subfamilies.

From Tables 1 and 2 it becomes evident that the proportionate availability of different taxa varies in different regions and indicates some pattern. Northeast India may be said to represent an ideal combination of physiography, climate and

Table 1. Abundance of aphids (species and genera) in different regions of India.

Subfamilies	NE India		NW India		Peninsular India		Gangetic Plains		Indus Plains	
	S	G	S	G	S	G	S	G	S	G
Anoeciinae	10	3	4	1						
Aphidinae	214	82	225	75	79	35	46	21	24	12
Callipterinae	35	21	33	15	7	6	4	2	2	1
Greenideinae	66	11	22	4	10	5	6	3		
Hormaphidinae	33	21	7	7	9	5	6	2		
Lachninae	18	8	27	10	1	1				
Pemphiginae	21	11	24	14	9	6	5	4	1	1
Total	397	157	342	126	115	58	67	32	27	14

S=Species; G=Genera

Table 2. Percentage of aphid abundance (species and genera) in different regions of India.

Subfamilies	NE India		NW India		Peninsular India		Gangetic Plains		Indus Plains	
	S	G	S	G	S	G	S	G	S	G
Anoeciinae	76.92	100	30.77	33.33						
Aphidinae	58.31	80.39	61.31	73.53	21.53	34.31	12.53	20.59	6.54	11.76
Callipterinae	53.85	70.00	50.77	50.00	10.77	20.00	6.15	6.66	3.08	3.33
Greenideinae	84.62	100	28.21	36.36	12.82	45.45	7.69	27.27		
Hormaphidinae	75.00	100	15.91	33.33	20.45	23.81	13.64	9.52		
Lachninae	48.65	66.66	72.97	83.33	2.70	8.33				
Pemphiginae	51.22	61.11	58.54	77.78	21.95	33.33	12.20	22.22	2.44	5.55
Total	61.55	77.72	53.02	62.38	17.83	28.71	10.39	15.84	4.19	6.93

S=Species; G=Genera

vegetation by embracing highest proportion of aphid taxa. Northwest India follows next. Both the Himalayan Regions individually support much higher proportion of aphid taxa than that available in the three other regions combined. The proportionate numbers of species and genera under different subfamilies in the five regions of India are shown in Table 2.

It appears in general that predominantly hilly terrains relatively abound in the number of aphid species. These regions are Northeast India, hereafter denoted as NE India, Northwest India, denoted as NW India, which includes Middle and West Himalayas, and the Indian Peninsula having the Eastern and Western Ghats and the Vindhya Ranges. The regions which are predominantly plainlands, i.e. the Gangetic and Indus Plains, are poor in aphid taxa.

ENDEMISM IN DIFFERENT REGIONS

As many as 359 species and 33 genera representing all the subfamilies are

endemic to India so far. This is about 55.66% of the total species recorded in this country. Although many of these "endemic" forms may in reality be common to adjoining countries (especially Nepal and southwestern China), high proportion of endemism of the species and the same of about 16.34% of the genera are indicative of the important situation of the Indian Subcontinent with regard to faunistics. The occurrence of the endemic genera and species under different subfamilies in different regions (Table 3) shows that, though NE India includes largest number of endemic genera and spcies, members of all the subfamilies are not represented in the same proportion. This indicates the ecological peculiarity of the region favouring speciation of one particular subfamily not any other. Conditions available in NE India perhaps favoured all but Lachninae and Pemphiginae for copious speciation as in all other subfamilies more than 60% of the endemic species could be found here. Largest proportion of about 62.96% of endemic species under Lachninae could be found in NW India indicating more congenial conditions for speciation of this subfamily. The same is corroborated by the find of largest number of species under this subfamily concentrated in this region. Speciation of pemphigine aphids was more or less equally favoured by the conditions available in both NE and NW India, which is also vindicated by the presence of more or less equal number of species in these two regions. It may be found from Table 3 that endemic species are somewhat quite high in number but endemic genera are much fewer.

The ratio of the endemic species to the total of the species in different regions and in India as a whole (Table 4) indicates that India provides situation for copious speciation of aphids or that this country is so placed that intrusion of species by dispersal is possible and later their occurrence became disjunct from the centre of origin. The proportion of endemic species is quite high under Anoeciinae and Greenideinae (more than 80%), it is least under Aphidinae (48%), and the other subfamilies contain about 55% to 60% of species as endemic. The members of subfamily Greenideinae have usually restricted distribution, being limited between about 45°S and 45°N latitude and between 40°E and 180°E longitude. The areas here delimited are southeastern portion of the Palearctic Region, whole of the Oriental and Australian and eastern portion of the Ethiopian Regions. These areas are influenced climatologically by oceanic rather than arctic conditions. Therefore, the

Table 3. Endemic species and genera in different regions of India.

Subfamilies	NE India		NW India		Peninsular India		Gangetic Plains		Indus Plains		Total in India	
	G	S	G	S	G	S	G	S	G	S	G	S
Anoeciinae	1	9		2							1	11
Aphidinae	11	107	10	93	1	13					17	177
Callipterinae	3	25	3	18		1					5	39
Greenideinae	1	59		12		3					1	63
Hormaphidinae	3	20	2	2		3					4	24
Lachninae	1	9	1	17	1	1					2	22
Pemphiginae	1	11	1	11		1			1	1	3	23
Total in regions	21	240	17	155	2	22			1	1	33	359

S=Species; G=Genera

Table 4. Ratio of endemic species found in India.

Subfamilies	NE India	NW India	Peninsular India	Indus Plains	Total
Anoeciinae	0.90	0.50			0.846
Aphidinae	0.50	0.41	0.16		0.482
Callipterinae	0.71	0.55	0.50		0.600
Greenideinae	0.89	0.55	0.30		0.808
Hormaphidinae	0.61	0.29	0.33		0.545
Lachninae	0.50	0.63	1.0		0.595
Pemphiginae	0.52	0.42	0.11	1.0	0.561
Total	0.60	0.45	0.19	0.037	0.557

occurrence of a greater proportion of endemic species in India might be quite logical. On the other hand the Indian members of Anoeciinae form only a small proportion of the world fauna but the species found under this subfamily are mostly endemic, and relatively high abundance of species is recorded in the western Palearctic and Nearctic Regions. Only one out of 13 species found in India is truly cosmopolitan. These again are restricted to areas along the Himalayan tract. The intrusive elements from the Palearctic Region might have adapted to the condition of Himalayas with necessary morphological changes to give rise to endemic species. Among the five regions of India no endemic species except one in Indus Plains could be recorded from any of the two Plain regions. These areas are mainly hot and humid or semi-arid and provide few ecological variations. These areas having mainly tropical climatic conditions contain less diversity of aphid species and most of the species recorded in these regions are eurythermic and cosmopolitan. Of the remaining three regions which are dominated by hilly terrains, NE India contains 60% of the species as endemic followed by NW India (45%) and Peninsular India (19%).

Endemism, thus estimated, has been found to be highly positively correlated with the total number of species found in different regions and in different subfamilies of aphids (r : on a level of 0.9 or 0.8). This is not, however, true for all places as only three regions of the five that have been considered here contain considerable number of endemic species. The trend of data indicates that after a certain level of availability of aphid species the rate of endemism increases more or less proportionately or at least by a certain factor. Existence of more species in any area has a logical bearing on the existence of ecological diversity that contributes to speciation and thus endemism. Absence of multiplicity of species and thus endemic species in the plain regions of India testifies to this postulation. Along with the less ecological diversity, the high mean temperature of these areas also stands in the way of aphid survival as has been indicated by Bodenheimer & Swirski (1957). The two regions of northern India largely having Himalayan tract and the southern Peninsula with high elevated ridges abound in large assemblage of diverse plants, which with the valleys and gorges and successively high altitude areas provide suitable conditions for the occurrence of large number of aphid species. This in reality led to the culmination of speciation. Incidentally the occurrence of somewhat lesser number of aphid species in Peninsula and much lower ratio of endemic

species to total number of species occurring there have to be viewd from some other aspect. The Peninsular India which is part of Gondwana land is old and very stable geologically and the associated flora and dependent fauna should eventually be distinct from the northern hill tracts and might have reached parallel climax.

The present day geography of the world may provide an idea of species prevalence, diversity and distribution but biogeographical evidence to this finding is difficult. This is particularly true of aphids as exploration of aphid fauna all over the present day landmass of the world has not been done with equal intensity; paleontological evidences are very poor bacause of the morphological characteristics of this group of insects (Richards, 1966) and further, establishment of apo- and plesiomorphic characters is difficult and much debated (Szelegiewicz, 1965). There is little doubt about the influence of the changing face of the earth on the distribution of organisms in time and space. The rift in the unit landmass, Pangea, formation of two major landmasses, the Laurasia of the Northern Hemisphere and Gondwanaland of the predominantly Southern Hemisphere, and the further rift and tectonic and orogenic movements which gave rise to the present day geography of earth may indicate primary commonness and affinity of flora and fauna. The effective isolation of units by barriers like Great Himalaya, Sahara, etc. served to delimit the genetic pool of organisms. Further, local influence of physiography, climate and vegetation on each of the biogeographical realms of Wallace acted in the species distribution and speciation as can be observed in the five regions considered here. The species richness, which has been analysed here on the basis of the number of species but not on the relative abundance of each species, has proved the contrary of analysis of beetles (Clarke, 1954) and dragonflies (Williams, 1964) where the number of insect species increases with the decreasing latitude. Aphid species richness, however, is more related to local ecological conditions than to latitude or broad climatic zones. Eastop's (1973) postulation that temperate countries have more diversity of aphids than the tropical countries should be viewed from the point of climatic peculiarity than of latitudinal/climatic zonations. The diversity of this phytophagous group of insects depends not on vegetational diversity alone but also on temperature and relative humidity, the vegetational diversity being more operative. India, though tropical and subtropical on latitudinal consideration, has great assemblage of arctic to tropical climatic conditions because of its physiography influenced by Himalayas and Peninsular hills, mountains and uplands, and monsoon influenced by wind currents from the Indian Ocean. This has led to more diverse and congenial ecological niches and habitats providing suitable situations for aphids to diversify with respect to species.

HOST PLANT-APHID ASSOCIATION

The types of species that become established are defined by the resources available at the site. The limit and extent of such site or area are rather difficult to define by any stable boundary. The topographic analysis of occurrence of species and their association with niches and habitats reveal some idea regarding limit of abundance. Aphids though obligate parasites of plants do not always occur with the occurrence of host plant species. Plant communities may be more important in considering the occurrence of aphid species or assemblage of aphid species (Ghosh

and Raychaudhuri, 1977).

Species of plants under about 137 plant families included in 86 plant orders belonging to 11 superorders have been recorded to harbour one or more of 645 aphid species occurring in India. Plants belonging to all these superorders have been found to be infested by aphids belonging to Aphidinae. Plants belonging to as many as seven superorders are infested by callipterine and lachnid aphids. However, the superorders are not the same for aphids of these two subfamilies. Callipterines have their host plants under superorders Asteridae, Caryophyllidae, Commelinidae, Dilleniidae, Hamamelididae, Magnolidae and Rosidae. The pemphigids infest plants belonging to Asteridae and five other superorders, on which callipterines also occur. The greenideines have their host plants in 7 plant superorders, five of which are common with those of pemphigids. Hormaphidines utilize plants under six superorders as hosts, five of which are common to pemphigids (pemphigids also occur on Magnolidae). Lachnids utilize plants of these six superorders and Gymnospermae. Anoeciine aphids have their hosts only in Arecidae, Commelinidae and Magnolidae. It may, therefore, be said that plants belonging to superorder Commelinidae contain hosts for aphids belonging to all the subfamilies, while those belonging to Asteridae, Dilleniidae, Hamamelididae and Rosidae are utilized by aphids belonging to all the subfamilies of aphids excepting Anoeciinae. Arecidae do not have any aphids belonging to Callipterinae and Pemphiginae. The plants of Magnolidae are infested by aphids belonging to Anoeciinae, Aphidinae, Callipterinae and Pemphiginae only. Plants of Caryophyllidae are infested by aphids of only two subfamilies, Aphidinae and Callipterinae, and Liliidae by aphids of Aphidinae and Greenideinae. Plants of Gymnospermae are preferred by some aphids of Aphidinae and Lachninae and plants of Alismatidae are used only by aphids belonging to Aphidinae (Table 5).

Species under Aphidinae infest plants mostly belonging to order Asterales (Table 6). These are infested by 128 out of 367 species recorded under Aphidinae. The next important plant orders infested are Rosales and Polygonales, which harbour 94 and 62 species under Aphidinae respectively. Nineteen and 14 species of Callipterinae infest plants belonging to Fagales and Sapindales respectively, forming quite a large proportion of the aphid species (65 spp.) that this subfamily contains in India. Greenideinae are second important subfamily containing 78 species, and, of

Table 5. Plant superorder and aphid subfamily relationship.

Plant superorders	Aphidinae	Anoeciinae*	Callipterinae	Greenideinae	Hormaphidinae	Lachninae	Pemphiginae
Alismatidae	2						
Arecidae	20	2		1	2	1	
Asteridae	188		8	34	2	2	4
Caryophyllidae	19		1				
Commelinidae	86	1	12	1	19	1	20
Dilleniidae	93		11	6	1	2	9
Liliidae	25			1			
Hamamelididae	37		25	52	9	7	4
Magnolidae	26	5	1				9
Rosidae	218		31	29	3	10	10
Gymnospermae	14					8	

* host plants known for 10 species only.

Table 6. Plant order and aphid subfamily relationship.

Plant orders	Number of infesting aphid species under:						
	Anoeciinae*	Aphidinae	Callipterinae	Greenideinae	Hormaphidinae	Lachninae	Pemphiginae
Aracales					2 (1)		
Araliales	2	20 (1)					
Asterales		128 (4)		5 (1)	2 (1)	2 (1)	3 (1)
Brassicales		18 (1)					
Celastrales		22 (1)					
Chenopodiales		24 (1)					
Cucurbitales		20 (1)					
Cyperales			4 (1)				3 (1)
Ericales		37 (1)					
Euphorbiales			5 (1)	7 (1)			
Fagales			19 (3)	41 (6)	7 (2)	7 (2)	
Geraniales		22 (1)					
Graminales	1	50 (2)	8 (2)		19 (5)		16 (4)
Guttiferales		18 (1)		5 (1)			
Juglandales			5 (1)	6 (1)			
Lamiales		35 (1)		26 (4)		2 (1)	
Laurales	5			10 (2)	6 (2)		
Leguminales		43 (2)	7 (2)	6 (1)			3 (1)
Malvales		21 (1)					
Myrsinales				5 (1)			
Myrtales		24 (1)	5 (1)	10 (2)			
Personales		26 (1)					
Pinales						14 (4)	
Polygonales		62 (2)					
Rosales		94 (3)	7 (2)	7 (1)		10 (3)	6 (2)
Rubiales		23 (1)					
Salicales			8 (2)				8 (2)
Sapindales			14 (3)				
Solanales	2	40 (2)		5 (1)			3 (1)
Urticales		18 (1)		5 (1)			
Verbenales		20 (1)					

Figures in parenthesis are notations for percentage of aphid species infesting (1) 5-10%, (2) 11-20%, (3) 21-30%, (4) 31-40%, (5) 41-50%, (6) 51-60%.
* host plants known for 10 species only.

these, 41 species infest plants under order Fagales. Hormaphidinae have 44 species recorded in India, and 19 utilize plant species under Graminales as their hosts. Pemphiginae, closely related to Hormaphidinae, contain 41 species and 16 of them use plants of Graminales as their hosts. Under Lachninae 37 species have been recorded and, of these, 14 species infest plants belonging to Pinales (Gymnospermae). The subfamily Anoeciinae is represented by only 13 species in India and, of these, 10 species are known by their hosts, and 5 species infest plants belonging to Laurales

Table 7. Number of plant orders infested by different proportion of aphid species.

Aphid species percentage	Number of plant orders used as host by					
	Aphidinae	Callipterinae	Greenideinae	Hormaphidinae	Lachninae	Pemphiginae
1-4	64	16	16	8	8	16
5-10	15	4	9	2	2	4
11-20	4	4	2	2	1	2
21-30	1	2			1	
31-40	1		1		1	1
41-50				1		
51-60			1			
Total no. of plant orders	85	26	29	13	13	23
Total no. of aphid species	367	65	78	44	37	41
Ratio-Aphid species: Plant orders	4.32	2.5	2.69	3.38	2.85	1.78

(Table 6). All this depicts affinity of the members of an aphid subfamily to a particular plant group. Aphidinae prefer species under plant orders Asterales and Rosales; Greenideinae and Callipterinae prefer Fagales; Hormaphidinae and Pemphiginae show affinity to plants belonging to Graminales and Anoeciinae to Laurales. It would appear, therefore, that all the aforesaid subfamilies select host plants exclusively from Angiospermae excepting some aphidine species feeding exclusively on pteridophytes and members of tribe Cinarini under subfamily Lachninae feeding exclusively on plants of Gymnospermae.

A small number of species under each aphid subfamily infest a good number of plant orders (Table 7). This suggests the extent of host acquisition capability of aphids in general. Species constituting upto 4% in Hormaphidinae could be recorded from plants under 8 orders, in Pemphiginae from plants under 16 orders, in Callipterinae on 16 orders, in Lachninae on 8 orders and in Greenideinae on 16 orders out of 13, 23, 26, 13 and 29 plant orders respectively used by their species as hosts. The plant orders serving as hosts for aphids forming less than 5% of species recorded under Aphidinae, Hormaphidinae, Pemphiginae, Callipterinae, Lachninae and Greenideinae amount to 75.29%, 61.54%, 69.57%, 61.54%, 61.54% and 55.17% respectively of the total plant orders acting as hosts of the aphids of these subfamilies.

HOST PLANTS AND POLYPHAGOUS APHIDS IN DIFFERENT REGIONS

Aphis gossypii Glover, *A. fabae* Scopoli, *Brachycaudus helichrysi* (Kaltenbach), *Myzus persicae* (Sulzer) and *Toxoptera aurantii* B.D.F. are a few of the highly polyphagous species and infest large number of hosts belonging to unrelated families. In spite of their polyphagous habit and because of their cosmopolitan distribution the number of host plants infested by them varies considerably. According to Eastop (1973) such variation mostly depends on the availability of host species but may also be due to other environmental factors that influence the host suitability. This

postulation may be vindicated by observations in the Indian regions (Table 8). Consideration of the host plant lists of these polyphagous aphids (Raychaudhuri, 1983) further reveals that they are all restricted to dicotyledonous plants. Of these *Toxoptera aurantii* is more specific to colonise only the tender twigs of woody dicotyledonous trees in all the regions and the rest of the aforesaid five polyphagous species may infest various parts including tender twigs, leaves, flowers, fruits, herbs, and trees and this nature of infestation is more common with *Aphis gossypii* and *Brachycaudus helichrysi*. There are, however, remarkable variations in the host plant species of these polyphagous aphids in different regions. Some plants are infested only in one region in India (Table 9), probably owing to the existence of specialised ecological conditions ('typical host plants'). This is true in the three hilly regions, whereas no typical host plants are found in the plain regions despite floral diversity there. Ecological factors other than vegetation must play a definite role in limiting host suitability (Ghosh and Raychaudhuri, 1977). The typical host plants in a region may be found in other regions but they are found to be unsuitable to be infested by the same aphid species. In the same manner some well known oligophagous aphids (Table 10) which enjoy wide geographic distribution may also change or acquire host plants either due to availability of botanically related plants or unsuitability of host plants in changed situations. *Aphis craccivora* (Koch) predominantly feeds on plants belonging to Leguminosae, *Lipaphis erysimi* (Kalt.) has

Table 8. Number of host plants of a few polyphagous aphids in different Indian regions.

Aphid species	NE India		NW India		Peninsular India		Gangetic Plains		Indus Plains		All Over India	
	Pf.	Psp.	Pf.	Psp.	Pf.	Psp.	Pf.	Psp.	Pf.	Psp.	Pf.	Psp.
Aphis gossypii	58	238	46	187	21	88	12	56	7	28	87	400
Aphis fabae	14	44	12	36	7	19	4	9	4	6	20	62
Brachycaudus helichrysi	26	98	21	53	11	37	5	10	3	7	34	131
Myzus persicae	27	147	16	86	10	47	6	18	4	11	35	200
Toxoptera aurantii	37	87	21	52	12	34	5	16	4	9	37	122

Pf.=No. of plant families; Psp.=No. of plant species infested.

Table 9. Number of host plants confined to only one region in India.

Aphid species	NE India		NW India		Peninsular India		Gangetic Plains		Indus Plains	
	Fam.	sp.	Fam.	sp.	Fam.	sp.	Fam.	sp.	Fam.	sp.
Aphis gossypii	7	11	6	11	3	5				
Aphis fabae	4	7	4	4	2	3				
Brahycaudus helichrysi	4	5	3	5	1	1				
Myzus persicae	6	8	5	6	2	2				
Toxoptera aurantii	5	7	7	8	3	4				

Fam.=plant families; sp.=Plant species.

Table 10. Hosts of some host specific aphids.

Aphid taxon	Host plant family	Number of host plant species					
		NE India	NW India	Peninsular India	Gangetic plains	Indus plains	Total in India
Aphis craccivora	Leguminosae	24	32	28	26	11	49
Capitophorus	Compositae	9	8	3	2	1	15
	Polygonaceae	15	12	4	5	4	16
Lipaphis erysimi	Cruciferae	15	16	13	13	12	16
Macrosiphoniella	Compositae	9	11	7	6	3	13
Uroleucon	Compositae	16	19	10	10	9	24

cruciferous plants as its hosts, the genus *Capitophorus* is more commonly found on plants of Compositae and Polygonaceae, and *Uroleucon* and *Macrosiphoniella* are more common on plants of Compositae.

It is difficult to deduce with any certainty how monophagism and polyphagism succeeded each other in aphids. In any case it has been inferred from the present day host association of aphids that morphologically old groups of aphids live more frequently on older groups of plants (Eastop, 1973). From the point of view of host selection and congregation of some groups of aphids on particular plant groups, Aphidinae have been regarded as recently evolved. Floral distribution is not partitioned by primitiveness and all places contain mixed vegetation. Particularly with respect to regions of India no such demarcation is possible and so almost all aphid subfamilies are represented in all the regions with rare exceptions. It is borne out that aphids probably evolved in temperate conditions and so more aphids species are found in regions akin to such conditions like Himalayas and Peninsular hills in India.

Exotic elements in Indian Aphididae

The find of exotic elements in India and its adjoining areas reveals that (Table 11) more species of Indochinese, Indomalayan and Japanese connection occur in NE India than elsewhere in India. But in NW India the exotic elements from Central Asia, Middle East and Mediterranean Regions are relatively more than Indochinese, Indomalayan and Japanese ones found in NE or Peninsular India. Immigration and colonization of plant species from widely different bordering countries are evident in Indian flora but the Malayan floristic elements are dominant. A similar pattern of intrusion is also evident in aphid fauna, and in all the three hill regions the Indochinese, Indomalayan and Japanese elements of aphid fauna are dominant. As the coniferous plants are mostly influenced by the flora from north of Himalayan ridge, the dependent aphids of Callipterinae and Lachninae are found more in NW India and presumably have intruded from Central Asia or even from Middle East. Ethiopian floral affinity has been established in Peninsular India but exact intrusive species of aphids from the same region are not yet known. Influx of floral elements into the temperate zones of southern parts of eastern Himalaya and preponderance of Malayan floristic elements along with a large proportion of African elements also

Table 11. Number of exotic elements of aphid species found in different regions of India.

Regions	Subfamilies	Indo-chinese	Indo-malayan	Japanese	Central Asian	Middle East	Mediter-ranean
NE India	Anoeciinae	1					
	Aphidinae	51	22	55	4	9	1
	Callipterinae	7		7			
	Greenideinae	10	7	2			
	Hormaphidnae	11	5	5			
	Lachninae	3	1	2		2	
	Pemphiginae	3	3	6		4	3
	Total	86	38	77	4	15	4
NW India	Anoeciinae	1		1	1	1	1
	Aphidinae	36	15	34	18	12	5
	Callipterinae	5		4	4	2	3
	Greenideinae	3	3				
	Hormaphidinae	3	3	2			
	Lachninae		1		3	4	1
	Pemphiginae	2	2	4		5	4
	Total	50	24	45	26	24	14
Peninsular India	Anoeciinae						
	Aphidinae	14	8	13	1	1	
	Callipterinae					1	
	Greenideinae	2	3				
	Hormaphidinae	2	2	1			
	Lachninae						
	Pemphiginae		2	1		2	1
	Total	18	15	15	1	4	1

have led to complex habitat and resource diversity leading to great divergence in aphid faunal complex in the present rather arbitrarily divided five Indian regions.

Aphid combination in different regions

The divergence of ecological features or habitat and resource (host plant/plant association/climate conditions) diversity is further revealed by the number of species found in combinations of any two regions (Table 12) and the same for common aphid species and genera found in such combinations (Table 13). Most of the genera and species found in India could be found in areas of NE and NW India taken together and the same is quite true when NE India is taken together with any of the other regions. A considerable decrease in their number is found when NW India is taken together with any of the three areas other than NE India and the decrease is remarkable when Peninsular India is taken together with any of the two plain regions. It transpires from these considerations that northern regions which are dominated by two extremes of Himalayan tract have maximum diverse habitat/resources for aphids and therefore abound in the numbers of aphid genera and species. Further, these two regions, i.e. NE and NW India, also serve as abodes for

Table 12. Total number of genera (above) and species (below) of aphids in combination of any two regions in India.

Regions	NE India	NW India	Peninsular India	Gangetic Plains	Indus Plains
NE India		200	178	159	158
NW India	604		151	129	127
Peninsular India	459	407		68	63
Gangetic Plains	416	368	151		37
Indus Plains	408	351	131	82	

Table 13. Number of genera (above) and species (below) of aphids common to combination of any two regions in India.

Regions	NE India	NW India	Peninsular India	Gangetic Plains	Indus Plains
NE India		83	37	30	13
NW India	135		33	29	13
Peninsular India	53	50		22	9
Gangetic Plains	48	41	31		9
Indus Plains	16	18	11	12	

the largest number of the same genera and species of aphids (Table 13), indicating great similarity of ecological conditions to contain higher proportion of common genera in any other combination of regions.

SUMMARY

Species diversity and prevalence of Indian Aphididae are closely connected with the biogeographical conditions of five regions. Cooler areas of NE and NW India exhibit higher concentration of species whereas hotter and drier areas of Indo-Gangetic and Peninsular India have less species diversity and poor prevalence. Even common plants in all the regions are not equally infested by aphids. Evidently, these insects have restricted their spatial diversity to cooler areas having diversified and rich flora. In north Himalaya, aphids are best represented in the altitudinal range of *c* 1200 m-*c* 1800 m. At higher altitudes only few species specific to plants of that area occur and at lower altitudes, in spite of floral richness, proportion of species abundance is far less (Ghosh and Raychaudhuri, 1977). Members of the subfamilies Callipterinae, Greenideinae and Hormaphidinae seem to be characteristic of the Indian fauna as most of the genera to which their species belong are either endemic to Indian region or distributed only in adjoining territories. This indicates the potentiality of the area for speciation. But species radiation does not seem to be much successful in these aphids in view of their limited diversity, restricted distribution and specificity in host plant association. The total number of species belonging to all the three subfamilies is much less than the number of species belonging to subfamily Aphidinae whose members are known from all the continents. Endemism in Indian Aphididae dominates in northern regions, and Indo-Gangetic Plains are virtually devoid of any indigenous aphid. Although greenideine

and drepanosiphine (put here under Callipterinae) aphids are comparatively better adapted to the hot and humid climate of Northeast India, their almost total absence from the plains of Indo-Gangetic and Peninsular Regions speaks of poor ecological conditions of these areas for the survival of aphids. Exotic elements of Indian Aphididae show faunal connection of India with Japan, Indochina and Malayan Regions. It seems that these aphids intruded into India along with their host plants and since then settled in new habitats. In spite of a large number of plant species adopted by Indian Aphididae, it is difficult to say how many of them are really the hosts. The present day host records of Indian Aphididae seem to be quite anomalous. Many species, seemingly host specific, have been recorded from widely unrelated plants. Many other species have their recorded host plants either incompletely identified or confused. In general, however, polyphagism is prevalent. True monophagous and oligophagous aphids are comparatively less in number and confined to NE and NW regions. Aphids in Indo-Gangetic Plains and Peninsular Regions represent mostly extended distribution of widely adapted polyphagous species. Out of 645 aphid species recorded, 604 species occur in NE and NW regions taken together.

Present day knowledge of Indian Aphididae is based on empirical studies and far from complete. Many areas of the five biogeographical regions are yet to be explored for aphid fauna. Particular references may be made to areas like Western and Eastern Ghats of the Peninsular India, Aravali, Satlaj and Shiwalik Ranges of Central and North India, and high altitude tracts all along Himalaya.

Besides, modern methodology in systematic research needs attention in order to deal the subject more comprehensively.

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References

Agarwala, Basant K. et Ghosh, A.K. 1984. A Checklist of Aphidoidea (Homoptera) of India. Rec. zool. Surv. India Occ. Paper 50 : 1-73.

Bodenheimer, F.S. et Swirski, F. 1957. The Aphididae of the Middle East. Weizmann, Jerusalem. 378 p.

Clarke, G.L. 1954. Elements of Ecology. John Wiley & Sons. xiv+560 p.

Eastop, V.F. 1973. Deductions from the present day host plants of aphids and related insects. *In* Insect/Plant relationship, ed. van Emden. 157-78 pp. Oxford : Blackwell.

Ghosh, A.K. 1980. The fauna of India and the adjacent countries. Homoptera, Aphidoidea, Part I. Chaitophorinae. 124 p.+xi.

Ghosh, A.K. 1982. The fauna of India and the adjacent countries. Homoptera, Aphidoidea, Part II. Lachninae. 167 p.+81 plates.

Ghosh, M.R. et Raychaudhuri, D.N. 1977. Stratigraphic distribution of aphids in Darjeeling district of West Bengal and Sikkim. Indian J. Ent. 39(3) : 262-270.

Raychaudhuri, D.N. 1980. Aphids of North East India and Bhutan. The Zoological Society,

Calcutta. 521 p.
Raychaudhuri, D.N. (ed.). 1983. Food Plant Catalogue of Indian Aphididae. Aphidological Society of India. 203 p.
Richards, W.R. 1966. Systematics of fossil aphids from Canadian Amber (Homoptera : Aphididae). Can. Ent. 98 : 746-760.
Szelegiewicz, H. 1965. Studies on the tribe Pterocommatini Mordv. (Homoptera : Aphididae) Part I. Phylogeny and Generic Classification. 23(10) : 251-300.
Williams, C.B. 1964. Patterns in balance of nature and related problems in quantitative ecology. London : Academic Press. viii+324 p.