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सत्यमेव जयते

G. S. Dhillon

कृषि मंत्री
भारत सरकार
नई दिल्ली—११०००१

MINISTER OF AGRICULTURE
GOVERNMENT OF INDIA
NEW DELHI-110001

November 26, 1987

MESSAGE

I am happy to learn that the Aphidological Society, India, is bringing out the inaugural issue of the Journal of Aphidology. The start of the journal is timely, keeping in view the rapid developments in research on aphids, which are important crop pests and vectors of several important plant diseases. I am sure the journal would maintain high standard and attract the attention of fellow Scientists from all over the world.

I wish all success to Aphidological Society and also to Journal of Aphidology.

Sd/-
(G. S. Dhillon)

सत्यमेव जयते

Dr. VASANT GOWARIKER
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GOVERNMENT OF INDIA
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DEPARTMENT OF SCIENCE AND TECHNOLOGY
TECHNOLOGY BHAVAN
NEW MEHRAULI ROAD, NEW DELHI-110016

November 11, 1987.

Message

I am glad to learn of the impending publication of the half yearly "Journal of Aphidology". This is an important subject having a bearing on our agricultural production. I only hope that the Aphidological Society will endeavour to ensure that the level and standard of articles appearing in the Journal and credible and able to command attention and respect among contemporary scholars. This can come about only through a rigorous system of refereeing.

I wish the Journal all success.

Sd/-
(VASANT GOWARIKER)

Telegram : PROTECTION

No, 83-1/87-BCD

GOVERNMENT OF INDIA

MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

(DEPARTMENT OF AGRICULTURE AND CO-OPERATION)

DIRECTORATE OF PLANT PROTECTION, QUARANTINE AND STORAGE

N. H. IV, FARIDABAD (HARYANA)

Dated : 11-12-1987

Message

I am happy to learn that The Aphidological Society, India has planned to publish a biannual Journal of Aphidology to promote the research work in the field of Aphidology. Earlier, this Society has been publishing a half yearly Newsletter which has been given warm reception by the Aphidologists all over the country as well as from abroad. The Newsletter has entered into Volume 6. It is also heartening to know the publications of the Society containing full papers of the National Symposia held at Agartala and Modinagar in 1985. Aphids are most important pests causing direct damage by sucking the plant sap as well as vectors of virus diseases. In many crops especially oilseed crops they are limiting factors in obtaining desired production. Success in the improvement of the productivity of oilseeds and other crops in India depends heavily on the efficacy of the plant protection umbrella provided to the crops. India has taken the lead in developing a detailed strategy for integrated pest management for major crops which admittedly involves appropriate integration of cultural, biological, mechanical, chemical methods besides the use of resistant varieties and surveillance. We have to continuously endeavour for and discover the most effective, low cost, safe and acceptable technologies. The results of which have to be published for the benefit of researchers, extension workers and farmers. In this context, the publication of Journal of Aphidiology will be most rewarding since it will provide the forum to share national and international experience and relevant techniques in the field of Aphidology. I congratulate office bearers of the Society on this occasion. I also wish the Journal of Aphidology every success.

Sd/-

(R. L. Rajak)

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No. F. PA/13/87/1771
November 30, 1987

Dr. S. P. Kurl
(Secretary, ASI)
Aphid Research Laboratory
Department of Zoology
MM Postgraduate College
Modinagar-201 204, U.P.

Message

Dear Dr. Kurl :

I am glad to note that The Aphidological Society, India is launching a half yearly journal **Journal of Aphidology** from 1987. I wish the venture all success.

If you can launch a good journal with a wide coverage of subjects and with papers from all over the world then, it would indeed be a big achievement and a major success of The Aphidological Society, India. With your proximity to Delhi, and the enthusiasm of the core office bearers, I am confident that the difficulties would not, be difficult to overcome.

We from the Institute shall be happy to extend assistance and cooperation in this regard.

With regards,

Yours sincerely,
Sd/-
(N. M. Nayar)
Director

सत्य मेव जयते

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FROM THE DESK OF THE

PRESIDENT

THE APHIDOLOGICAL SOCIETY, INDIA

The Aphidological Studies in the World have gained a new dimensions in the decade of eighty, with international meets, a number of significant contributions in newer areas of works and better understanding of tropical aphids. The Indian aphidologists as a group, one has to admit, had their own share of contributions and they even ventured to form a society, to exchange ideas and make co-ordinated efforts in solving many an unsolved mystery. The new journal from the society will further testify to the sincerity of motivation of a group of scientists work in this vast subcontinent. The association of well known aphidologist from other parts of the World will undoubtedly lead valuable support to this venture. I sincerely look forward to rewarding reading in the 'Journal of Aphidology' and wish all success.

Sd/-
(A. K. Ghosh)
President
The Aphidological Society, India

November 12, 1987

THE APHIDOLOGICAL SOCIETY, INDIA

(Estd. 1979) Registration No. 1—10969 (M)

Secretary :
Dr. S. P. Kurl

Head Office :
C/o Aphid Research Laboratory
Department of Zoology
M. M. Postgraduate College
Modinagar-201 204, India

Dated : *30-12-1987*

SECRETARY'S NOTE

With immense pleasure, the Society bring to your hands the inaugural volume of the Journal of Aphidology. It has been a long cherished wish of all the Aphidologists that an exclusive journal be published to ventilate their thoughts and research results of aphid researchers. It is heartening to note that we are receiving many interesting research manuscripts from scientists at home and from abroad. I am sure that since the beginning is made, we would be able to keep up a high standard of the Journal so that it would catch international attention with which the progress made in India in various spheres would be known and widely appreciated.

It is essential that the contributors would keep in mind about the perfection in their articles with regard to style and contents as given in the 'Instructions to Authors'. The perfection of the journal lies in the excellence of articles that are published. So the thrust of the Sciety is to publish such work that would attract good interest from the world over. This attempt is a step towards keeping the Society alive and active, as is generally felt in the scientific community.

The Society could keep up this tempo only due to the support from its members. We have tried our best to bring this volume out in good shape. Any suggestions for improvements are welcomed. I hope that all the readers would enjoy its contents.

Sd/–
(S. P. Kurl)

J. Aphidology 1 (1 & 2) : 1–4, 1987

KEY TO SUBGENERA OF *ERIOSOMA* LEACH (APHIDIDAE : HOMOPTERA)

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SUMMARY

A key is given to discriminate subgenera for all the viviparous morphs of the genus *Eriosoma*.

INTRODUCTION

Identification of specimens belonging to the aphid genus *Eriosoma* Leach 1818 is still fraught with difficulties, despite the considerable elucidation in recent years of the Japanese (Akimoto 1983 : 37–106), Indian (A. K. Ghosh 1984 : 15–58), European (Danielsson 1979 : 193–208, 1982: 341–358) and American (C. F. Smith 1985 : 291–297) fauna. These difficulties will inevitably persist until the sometimes complicated life cycles of all the species have been clarified. Even the subgeneric classification is controversial, although most recent authors have used *Eriosoma* s. str. for some North American species and *Schizoneura* Hartig, 1839 for some Old World species.

OBSERVATIONS

While trying to identify the accessions in the British Museum (Natural History) it was observed that the species seemed to fall into five groups, for all of which genus group names are available. A key has been constructed for all the parthenogenetic viviparous morphs of these five groups. Too few sexuales have been seen to make keys for them. The five groups recognised are :—

Eriosoma s. str. Rosette galls on *Ulmus* of the *americana* group and with exules in woolly masses on *Pomoidea*. *E. rileyi* does not produce galls or alternate to secondary hosts but apterous sexuparae develop on *Ulmus* in the autumn. Six species of North American origin, but the woolly apple aphid is now widespread.

Georgiaphis Maxson and Hottes, 1926. Curling leaves of *Ulmus alata* and *U. rubra*, without host alternation. Alate sexuparae develop early in the summer. Two species known only from North America.

Mimaphidus Rondani, 1848. Crumpling or galling the leaves of *Ulmus* s. str. and with exules on the roots of *Pomoidea*, *Senecio* and more rarely other plants.

At least one species lives on *Ulmus* without host alternation, producing alate sexuparae in the summer. About 8 Old World species.

Schizoneura Hartig, 1839. Curling the leaves of *Ulmus* s. str. and alternating to the roots of Grossulariaceae and other plants. About 15 Old World species, one of which does not distort leaves itself, but usurps the galls of other species.

Colophina Börner, 1932. Alternating between *Zelkova* and *Clematis* in eastern Asia. Three species perhaps really belonging to a different lineage with *Hemipodaphis* and *Byrsocryptoides* see Akimoto, 1985 : 19.

The various morphs of the different subgenera are discriminated in the following key.

Key to the morphs and subgenera of *ERIOSOMA* Leach

1. Apterae without siphunculi and with 3–6 segmented antennae. In distorted leaves of Ulmaceae (fundatrices)................................ 2
   — Apterae with siphunculi, and alatae 7

2 (1). Antennae 3-segmented. On *Zelkova*............................*Colophina*
   — Antennae 5 or 6-segmented. On *Ulmus*...................................... 3

3 (2). Tarsi cylindrical, the second segment of the hind tarsus about 5½ times as long as its basal width. Antennae 6-segmented. In rolled leaves ....*Schizoneura*
   — Tarsi tapering, the second segment of the hind tarsus 3–4 times as long as its basal width. Antennae 5 or 6-segmented..................... 4

4 (3). Antennae 6-segmented. In crumpled leaves ....
   ....*Mimaphidus* in part, *patchiae* group
   — Antennae 5-segmented 5

5 (4). Third antennal segment equal in length to fourth and fifth together. Cauda with 3 hairs. Lateral distal hairs on second tarsal segments the longest. In more or less closed galls ....
   ....*Mimaphidus* in part, *lanuginosa* group
   — Third antennal segment about 1–2 times as long as the fourth and fifth segments together. Dorsal and lateral distal hairs on second tarsal segments similar in length or the dorsal hairs the longest. Cauda with 2 hairs...................................... 6

6 (5). Dorsal distal hairs on second tarsal segments much thicker than the lateral distal pair. Paired glandular areas on spinal areas of abdominal tergites 2–5 wider than the distance between them. In rosette galls..*Eriosoma* st. str.
   — Dorsal and lateral distal hairs on second tarsal segments similar to one another. Glandular areas on abdominal tergites 2–5 smaller, not as broad as the distance between each pair. In curled leaves ....*Georgiaphis*

7 (1). Apterae viviparae with siphunculi.. 8

— Alatae viviparae with siphunculi..11

8 (7). Tarsi spinulose, tapering towards apex. Intersegmental membrane between antennal segments V and VI narrow. Either in galls or crumpled leaves of *Ulmus* or exules on the roots of Rosaceae or *Senecio*, or more rarely other plants...............................*Mimaphidus*

— Tarsi smooth and not tapering. Antennal V and VI usually evidently articulated. Exules on the roots of Grossulariaceae and more rarely other plants, or aerial parts of roots of Rosaceae.........................9

9 (8). Abdomen with eight or more longitudinal rows of wax plates, including a latero-ventral row. In woolly masses on *Clematis* ....*Colophina*

— Abdomen with only lateral and spinal paired rows of wax plates...10

10 (9). Central areas of wax plates with small facets. Mostly on Rosaceae ....*Eriosoma* s. star.

— Wax plates with a large clear central areas. Mostly on roots of *Ribes*........... ....*Schizoneura*

11 (7). Secondary rhinaria irregularly and widely spaced, about $\frac{1}{2}$ to equal the diameter of the segment apart and only encirculing about one third of the circumference of the segment. First segments of hind tarsi bearing a 'sense peg' in addition to the pair of lateral hairs. Sexuparae, without wax glands, leaving curled leaves of *Ulmus* in early summer...*Georgiaphis*

— Secondary rhinaria more regularly and closely placed, about $\frac{1}{3}$–$\frac{1}{2}$ the diameter of the segment apart, and encompassing at least half the circumference of the segment...12

12 (11). Fifth antennal segments bearing 14–20, and base of sixth antennal segment bearing 6–11 rhinaria. On *Zelkova* and *Clematis* ... *Colophina*

— Fifth and sixth antennal segments with fewer secondary rhinaria.....13

13 (12). Antennal V and VI without secondary rhinaria. Primary rhinarium on antennal V with ciliated margins. Sexuparae (embryos without mouthparts) with antennal V and VI not freely articulated and wax plates consisting of clear areas surrounded by a broad dusky border. Mostly in rolled leaves of *Ulmus* or from the roots of *Ribes*..*Schizoneura*

— Antennal V and sometimes also base VI bearing secondary rhinaria. Primary rhinarium on V rarely ciliated.......................................14

14 (13). Embryos with mouthparts (fundatrigeniae and exules), was gland plates little evident...15

— Embryos without mouthparts (sexuparae), wax gland plates sometimes evident..........18

15 (14). First segments of hind tarsi bearing a sense peg in addition to the pair of fine hairs..........*Eriosoma* s. str., in part

— First segments of hind tarsi bearing only a pair of fine hairs..........16

16 (15). Apices of tibiae and first and second tarsal segments strongly spinulose. Primary rhinarium on antennal V with ciliated margin ....*Mimaphidus patchiae* group

— Only the second tarsal segments spinulose. Primary rhinarium on V not ciliated..........17

17 (16). Eighth abdominal tergite bearing 2 (–4) hairs; third antennal segment bearing 6–9 hairs. From woolly masses on Rosaceae ....Exules of *Eriosoma*

— Eighth abdominal tergite bearing 4–8 hairs; third antennal segment bearing 10–19 hairs. From galls or crumpled leaves of *Ulmus* ....Fundatrigeniae of *Mimaphidus lanuginosum* group

18 (14). Wax plates evident, primary rhinarium of antennal V sometimes ciliated ....(*Mimaphidus*)19

— Wax plates absent or almost completely atrophied. Primary rhinaria not ciliated..........*Eriosoma* s. str.

19 (18). Wax plates a clear space surrounded by a broad dusky rim. Primary rhinaria not ciliated..........*Mimaphidus lanuginosa* group

— Wax plates a ring of cells around a clear facetted area. Primary rhinarium on V with ciliated margin..........*Mimaphidus patchiae* group

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APHID TRANSMISSION OF PLANT VIRUSES IN INDIA

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SUMMARY

Aphids outnumber other vector groups both in terms of the vector species and the viruses involved. The relationships of aphids with the viruses that they transmit are as diverse and intricate as their biology which has been discussed with special reference to the nonpersistant type of transmission which is a monopoly of the aphids. The current concepts on the mechanism of nonpersistant transmission, which has remained a highly controversial subject, have been dealt in details based on the evidences obtained through the application of various techniques like electron microscopy, radio tracers, electronic monitoring of aphid probing and feeding and highly sensitive serological detection.

Besides providing a glimpse of the diversity and magnitude of the problems of aphid-borne virus diseases in India, a critical analysis of the known and potential vector species has been presented, pointing out the gaps in knowledge to be overcome in order to evolve sound management strategies.

INTRODUCTION

The notoriety of aphids as vectors of plant viruses has tended to obscure the magnitude of their direct damage due to feeding. While crop losses due to feeding of aphids are caused only when they occur in large numbers, a few individuals acting as virus vectors may severely affect the yield.

Aphid-transmitted viruses cause severe crop losses throughout the world, infecting numerous economic plants including cereals, legumes, vegetables, fruit trees and ornamentals. The cash value of such losses will certainly add up to staggering figures but the estimations would be largely fictitious due to the rapidly changing money value. It would be more meaningful to state that virus diseases affecting potato, sugarbeet, wheat, legumes etc. may reduce yield in terms of tons/acre. Citrus tristeza virus accounted for the loss of 7 million orange trees in the state of Sao Paulo, Brazil. Citrus tristeza virus also occurs in India along with many other aphid-borne viruses, which will be discussed later.

The Japanese workers were the first to provide evidence of the involvement of insects in the spread of plant virus toward the beginning of the 20th century, nearly four decades before the true nature of viruses was discovered. They demonstrated the transmission of rice dwarf disease by two species of leafhoppers. The first authentic record of an aphid vector was that of *Aphis gossypii* Glover from the U. S. A. in 1916, the virus being cucumber mosaic. Four years later, *Myzus perrsicae* (Sulzer) was detected as a vector of potato leaf roll virus in The Netherlands. The significant discovery paved the way for intensifying research to prevent the so called "degeneration of potato stocks". The number of vector species and the number of viruses transmitted by aphids have since soared, outnumbering all other vector groups on both the counts.

Apart from the numerical superiority, the intricacy and diversity of aphid-virus relationships are matchless. In fact, the classification of vector-virus relationships have grown and developed over the years predominantly on the basis of studies on aphid transmission. Thus, we owe our concepts on nonpersistent, semipersistent, bimodal and the entire range of dependent transmission to aphids and aphid-borne viruses.

Knowledge of the Indian aphid fauna has been considerably enhanced during the last two decades but very little is known about biology of different species under the diverse ecoclimatic conditions of this vast subcontinent. Aphids are abundant in the plains during the winter and spring, but their activity during the other seasons is generally obscure. Unlike aphids under temperate conditions, which prevail in the hills at high altitudes, the problem of the species inhabiting the plains is not to overwinter but tide over the summer. Records of sexual forms of a number of Indian aphids in recent years are restricted to morphological descriptions without any information about its significance in overall biology of the species. Under Indian conditions, their reproduction is almost entirely parthenogenetic, the females being viviparous, giving birth to females only. This point should be borne in mind while investigating into the aphid oriented problems in Indian agriculture.

In order to tackle aphid-borne viral problems, an insight into the vector-virus relationships is essential along with biology and ecology of the vector species. The present paper is intended to draw attention to the same in the Indian context.

VECTOR–PLANT INTERACTIONS

Vector's feeding apparatus and sensory transduction :

Since the mouthparts are the direct means by which the aphids pierce the plant tissue, extract sap and in the process acquire/inoculate the plant viruses, a brief discussion of the ultrastructures and their possible functions is pre-requisite for proper understanding of the transmission mechanisms.

Within each mandibular stylet is a central or axial duct, running from the base to the tip and contains two dendrites that monitor the substrates present at the tip of stylets. Both the mandibular and the maxillary stylets have a series of tooth-like projections which serve to anchor the stylets into the plant tissue during penetration. Pressure of the haemolymph on the walls of the labral and labial canals may also aid the clamping and guiding action besides the labium.

The precibarium has a small precibarial valve which appears to act as a regulator of fluid flow into the cibarium as well as a pressure sensitive check valve, preventing back-flow into the stylets (McLean and Kinsey 1984). The importance of the precibarial region is particularly for the location of the so-called epipharyngeal gustatory organ. Following Backus, we prefer to name the same as precibarial chemosensilla which is more appropriate. It is through these chemosensilla that the homopterans taste plant chemicals and as such they are vital for mediating host selection.

Probing is accompanied by salivation with the formation of salivary flange with the labial tip first contacts the plant surface. Secretion of the salivary sheath continues as the stylet bundle penetrates between cells to phloem. Recently, aphid saliva has been found to possess hemicellulase, cellulase and several other polysaccharases, including the usual digestive enzymes, whose presence and activity is correlated to specific host plants (Dreyer and Campbell 1984 ; Campbell and Dreyer 1985).

The sensory transduction system equips aphids to detect and analyse mechanical and chemical stimuli from potential host plants. Most aphid sensory organs used in host selection and feeding are antennal sensilla (Shanibough *et al.* 1978 ; Dunn 1978 ; Bromley *et al.* 1979) ; labial sensilla (Tjallingi 1978 ; Wensler and Filshie 1969) ; internal stylet sensilla (Forbes 1966 ; Wensler 1974) ; and internal precibarial sensilla (Wensler and Filshie 1969).

Ultrastructural studies of the eight paired labial sensilla in *Brevicoryne brassicae*, indicate that these receptors elect both surface contact (pressure) and surface profile and are probably mechanosensitive (Wensler and Filshie 1969 ; Wensler 1974 ; Tjallingi 1978). As the insect inserts its stylets into the plant tissue, it again senses both mechanical and chemical cues. The mechanical stimuli are detected by the stylet sensilla. Sensory innervation of mandibular stylets consist of two groups of sensory neurons, each with a short dendrite extending into and ending in base of the stylet and another dendrite with long tubular process extending to the distal tip of the mandible. Wensler (1974) proposed that the homopteran stylet organs are proprioceptive mechanosensilla and hypothesized that these dendrites monitor the latero-medial movement of the stylet tips and its direction of penetration.

Chemoreception via feeding apparatus appears to be limited to precibarial chemosensilla. Each papilla is innervated by a number of neurons with dendrites that end at definite pores to the lumen of food canal. Consequently, these sensilla make direct contact with ingested food passing through the food canal and equip the aphid to select chemical stimuli after the stylets have penetrated the plant surface. The relevance of the above information would be evident during discussions on the transmission mechanism.

VECTOR-VIRUS INTERACTIONS

Two classification systems have been used to describe virus transmission by aphids. The first one was proposed by Watson and Roberts (1939) who grouped them into nonpersistent (NP) and persistent (P), based on the retention of infectivity of the vector following acquisition of virus.

The NP viruses have the characteristics of being acquired during probes as brief as a few seconds and can be transmitted immediately after acquisition through equally brief probes. One very significant feature is the pronounced beneficial effect of fasting before acquisition on transmission. The enhanced efficiency in transmission was earlier attributed to saliva-free probes. According to recent concepts, preacquisition fasting changes the probing behaviour of aphids, resulting in brief exploratory probes which are predominantly intracellular. Such direct sap sampling is particularly congenial to NP transmission. Understandably, prolonged acquisition/inoculation access decreases the probability of transmission. Infectivity is retained for a short period of time, measurable in terms of minutes to hours and is lost with moulting of the vector. A NP virus is not recoverable from the haemolymph and the vector does not become infective when the virus is inoculated into the haemolymph.

The persistent viruses on the other hand, require prolonged periods of feeding and longer the feeding, better the chances of acquisition. There is always a detectable latent period after acquisition, for the aphid to become infective. Infectivity is retained much longer, for several days and weeks and often throughout life and is not affected by moulting. The virus is recoverable from the haemolymph and the vector becomes infective when purified virus is injected into the haemolymph.

Semipersistent (SP) viruses (Sylvester 1956) resemble the persistent viruses in that they are not acquired during brief probes and preacquisition fasting has no beneficial effect on transmission. The probability of transmission increases with increased acquisition feeding. They differ from P viruses in that there is no detectable latent period and the infectivity is lost by moulting. As in NP viruses, the virus is not recoverable from the haemolymph. Aphids can retain SP viruses usually for 1–2 days only. Since the retention time for a given viruse-vector combination can vary greatly, differentiation of the three categories is sometimes difficult with viruses not precisely fitting into any one category.

The second and the newer system of grouping plant viruses was proposed by Kennedy *et al.* (1962), classifying viruses as stylet-borne and circulative, replacing NP and P, respectively. This classification was based on the route of virus transport.

The term, stylet-borne, gave recognition to the findings of Bradley and Ganong (1955 a, b) about rendering the viruliferous aphids nonviruliferous by treating the stylet tips with antiviral agents like formalin and UV irradiation. The term, circulative, refers to virus transmission in which the virus is acquired via the maxillary food canal, absorbed through the midgut wall to the haemolymph, translocated to the salivary glands and eventually inoculated into plants through the virus-laden saliva ejected from the salivary canal.

The drawback of this classification is that it provides no room for SP transmission. Besides, the very term stylet-borne tends to convey the impression that infection is caused by mechanical contamination and decontamination of the stylet surface. Secondly, the adoption of this term on the basis of supposed inactivation of the viruses on stylet tips is equivocal as it might also affect transmission by altering feeding behaviour of the vector.

In this connection, it should be pointed out that NP or the so called stylet-borne transmission is a monopoly of the aphids and roughly two-third of the aphid transmitted viruses belong to this category. Expectedly, it has been the most worked out and controversial aspect of transmission with various hypotheses proposed time to time.

Although the term, stylet-borne met wide acceptance initially and readily replaced NP, later findings yielded convincing evidences about shortcomings of the term. In view of the wide prevalence and economic importance of the NP viruses, the mechanism of transmission requires a critical analysis as it has direct bearing on epidemiology and management of diseases caused by such viruses.

Since it is not feeding but brief probings are congenial for successful acquisition and inoculation of NP viruses, what aphids do during brief probes is of paramount importance in order to understand the mechanism of transmission. Findings in recent years have adequately revealed the unique superficial sap sampling behaviour of aphids. Even during brief host selection probes, the volumes of plant sap that are ingested (480–841 μm^3), are many times greater than what could be physically accommodated in the maxillary food canal lumen (Garret 1973). This host selection behaviour brings the ingested sap in contact with the precibarial chemosensilla which determine suitability of the plant as a host. Sap sampling on virus affected plants, therefore, not only contaminate the stylet tips but more so the maxillary food canal and the foregut. Subsequent sap sampling from healthy plant results in completion of the transmission cycle when the virus-laden material ingested earlier, is egested along with freshly drawn sap of healthy plants. Thus, it is not only the stylet surface but the entire area from the stylet tips to the foregut, is involved in the transmission process, like an injection syringe and not merely as an inoculating needle as understood earlier.

Recently, using enzyme-linked immuno-sorbent assay (ELISA), Gera *et al.* (1978) were able to detect an aphid transmissible strain of cucumber mosaic virus (CMV) associated with viruliferous aphids. No reaction was obtained with aphids that had been exposed to a non-transmissible strain of CMV. The researchers suggested aphid transmissibility or nontransmissibility to be determined by ability or inability respectively, of the virus to attach to the stylets. Later experiments (Gera *et al.* 1979) however, clearly showed ELISA detection of CMV to be almost entirely associated with foregut.

The above discussions clearly show the limitations of the term, "stylet-borne", and as such the categorisation of aphid transmitted viruses proposed by Harris (1977) is quite rational. The viruses are first broadly grouped as noncirculative and circulative. Noncirculative is subdivided into nonpersistent and semipersistent, thus providing the latter a berth. The term, circulative replaces persistent since the persistent viruses are invariably circulative. Circulative viruses which propagate within the vector are to be termed as circulative propagative.

A few notable examples of the different categories of aphid-borne viruses which occur in India are :

Noncirculative :

Nonpersistent : Potato viruse Y, Cucumber mosaic virus, Papaya mosaic virus.

Semipersistent : Citrus tristeza virus.

Circulative : Potato leaf roll virus, banana bunchy top, barley yellow dwarf virus.

With the bare essentials of aphid-virus relationship, we now pass on to the viral problems and the vectors in India.

APHID TRANSMITTED VIRUSES IN INDIA

Aphid transmitted viruses in this country affect a large number of cultivated crops, fruit trees, ornamentals and medicinal plants besides infecting numerous weeds. It is beyond the scope of the present paper to enter into the details of the same and only a brief survey of the large body of information will be attempted to provide a glimpse of the diversity and magnitude of the problem.

It must be pointed out in this connection that virus diseases are almost always named on the basis of symptoms exhibited by the infected plant. But similar symptoms may be expressed by the same plant species due to infection of another virus. For example, mosaic symptoms of chilli may be caused by several distinct viruses namely, potato virus X (PVX), potato virus Y (PVY), and CMV, of which PVX is not aphid transmissible. It is, therefore, necessary to establish the identity of a virus for proper understanding of vector-virus relationship. Etiological studies are badly required for a large number of virus diseases in this country.

Among the graminaceous crops, rice is totally free from any aphid-borne virus. Wheat crop in India is apparently free from many virus diseases which affect the crop in the western world but barley yellow dwarf virus (BYDV), which is potentially destructive and the most widespread of the cereal viruses in the world, has long been recorded from India. Since its first record from the Simla hills (Nagaich and Vashist 1963), the occurrence of BYDV has been observed in the Kumaon hills and also in the plains of North India and Karnataka. Fortunately, no large scale epiphytotic has so far been reported from wheat growing belts (Basu and Niazi 1986). Sugarcane mosaic virus, which also infects maize under natural conditions, is common but apparently not injurious enough to create concern.

Leguminous crops are affected by a number of aphid-borne viruses and mosaic symptoms are commonly encountered on beans, cowpea, soybean and pea in different parts of the country. Some of these viruses must be causing appreciable damage but there has been no study on the overall impact of these viruses on yield losses in various parts of the country.

As regards viruses of solanaceous crops, the potato viruses, particularly PVY and potato leaf roll virus (PLRV) are major constraints to the cultivation of the crop in India as in many other countries. Mosaic of chilli is very common and is caused by several viruses which include the chilli mosaic virus, PVY and CMV, all being nonpersistently transmitted by several species of aphids. While the classical tobacco mosaic virus (TMV) has no homopteran vector, the mosaic of tabacco caused by CMV is vectored by aphids.

Mosaic symptoms on various cucurbitaceous crops are encountered throughout the country which seem to be caused mainly by CMV.

A mosaic disease of radish and *Brassica juncea*, caused by a strain of turnip mosaic virus, is extremely common in the eastern hills and also occurs in Uttar Pradesh and Delhi. Out of several species of aphid vectors, *Lipaphis erysimi* (Kalt.) was found to be the most efficient (Ahlawat and Chenulu 1982).

Of the aphid-borne viruses of fruit plants, the mosaic of papaya is very common and widespread, affecting the quality and yield considerably. Citrus tristeza virus is one of the major agents causing citrus decline. Fortunately, the severe strain of the virus is restricted to several areas which is very efficiently transmitted by *Toxoptera citricidus* (Kirkaldy).

The *Foorkey* or dwarfing disease is a serious constraint to the cultivation of large cardamom, a vitally important cash crop in the hills of Darjeeling district and Sikkim. In terms of prevalence and the nature of damage, this disease is much more important than the *Chirke* or mosaic streak virus of the same crop. The latter virus is interesting as it is capable of infecting wheat and the common cereal aphids efficiently transmit the virus from large cardamom to wheat and from wheat to wheat (Basu and Raychaudhury 1972). The highly prized small cardamom crop in the south is affected by cardamom mosaic virus, causing the so called *Katte* disease, the vector being *Pentalonia nigronervosa* Coquerel. The same aphid also transmits the banana bunchy top virus, a very important disease of banana.

Many other economic plants, including ornamental and medicinal ones, in this country are known to be affected by aphid-borne virus diseases which are not being discussed for the sake of brevity.

CRITICAL NOTES ON THE INDIAN APHID VECTORS

Screening tests to find out the aphid vectors of different virus diseases in India, have been restricted to the tribes Aphidini and Macrosiphini with rare exceptions. One notable example is that of *Tetraneura nigriabdominalis* (Sasaki), which could transmit Eleusine mosaic (Rao *et al.* 1965).

While most viruses have several aphid vectors, banana bunchy top and *Foorkey* of large cardamom are so far known to be transmitted by single vector species.

A strong bias for species like *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover is quite evident which is understandably due to their highly polyphagous nature. In transmission trials, aphid species have often been found to infect nonhosts with noncirculative viruses, not only nonpersistent ones but also a semipersistent virus. The transmission of mosaic streak of large cardamom by *Brachycaudus helichrysi* (Kaltenbach) ; broad bean mosaic by *Macrosiphoniella sanborni* (Gillette) ; papaya mosaic by *Uroleucon sonchi* (L.) ; radish mosaic by *Rhopalosiphum maidis* (Fitch), *Schizaphis graminum* (Rondani), *Toxoptera odinae* (v. d. G.) and *T. citricidus* (Kirkaldy) ; and the transmission of citrus tristeza by *Uroleucon* (*Uromelan*) *jaceae* (L.) are some example of this kind.

Some aphids which are well known as highly efficients vectors in the temperate countries, like *Aulacorthum solani* (Kaltenbach), *Neomyzus circumflexus* (Bckt.), *Macrosiphum euphorbiae* (Thomas) and *Myzus ornatus* Laing, do occur in India but seem to be restricted to the hills. The vector problems in the hills would naturally be altogether different from those in the plains.

Intensive studies by the first author over the years on the biology and ecology of some important vectors, strongly indicate that the importance of a few aphids, particularly *M. persicae*, has been overestimated. The notoriety of the species as an extremely efficient and the most prolific vector of plant viruses is undeniable which accounts for its inclusion in almost all screening tests to determine vector species involved in transmission of a virus. The findings of such experiments have resulted in an ever increasing list of plant viruses to be vectored by *M. persicae*. But the validity of such experimental findings in terms of actual involvement of the aphid under field conditions generally goes unconfirmed. The bias for such a few highly notorious vectors has apparently accounted for ignoring some aphids which may be the real culprits under natural conditions during certain seasons.

The situation seems to have arisen due to lack of consideration of two very vital issues, firstly the phenology of the vectors and secondly, the basic mechanisms of nonpersistent transmission. Findings of the first author adequately revealed a number of important viruses, particularly those belonging to potyvirus and cucumovirus groups, to be prevalent in the fields when *M. persicae* was extremely scarce or not traceable at all. In fact, *M. persicae* is active in the plains for barely 4-5 months and as such other aphids must be involved and have to be screened and documented. It seems worthwhile to refer in this connection the pioneering studies on the epidemiology of the potato aphids in West Bengal by Banerjee and Basu (1956). Their findings clearly showed the prevalence of *M. persicae* on potato near Calcutta throughout the growing season of the crop, but *A. gossypii* was much more numerous then *M. persicae*. The object of the discussion is not to undermine the importance of *M. persicae* but just to point out that the formidable records of the species should not divert attention and leave other aphids out of consideration.

Aphis gossypii is perhaps the commonest aphid in this country and its importance as vector is enhanced by its occurrence throughout the year. *Aphis craccivora* Koch is common enough to deserve more attention as a vector. Very little is known about the role of *Aphis fabae* complex in this country as is also the case with *Aphis citricola* v. d. G. . *Hysteroneura setariae* (Thomas) has remained neglected and its potentiality as a vector has not been studied and the same holds true for several other species.

The best way to keep track of the potential vectors is to monitor the aerial populations of aphids through out the year through the use of traps. The trap data would not only reveal the relative prevalence of the different aphids at different times of the year but would also help in determining the involvement of a species in field spread of a virus. It would however, require a background in aphid identification and correct indentification of the vector is essential to initiate investigations on vector-borne diseases. If a species is wrongly implicated as vector of a virus, it is bound to mislead future workers, resulting in confusions and consequent lack of direction to arrive at the truth. The *Foorkey* disease of large cardamom for instance, had been reported to be transmitted by the banana aphid, *P. nigronervosa* (Vasudeva 1956 ; Varma and Capoor 1958) but not even a single plant could beinfected through the aphid during subsequent transmission tests with hundreds of plants. Ultimately, *Micromyzus kalimpongensis* Basu was found out to be the vector (Basu and Ganguly 1968) and this valuable finding paved the way for screening large cardamom varieties for resistance against *Foorkey*.

Vector-virus relationship studies have to be adequately backed up by vector biology and ecology to devise ways and means to curb losses due to virus diseases. The value of such information will be evident from the success of the seed plot technique to raise disease-free seed potatoes. Years of survey, carried out mainly at Patna and Jalandhar stations of the Central Potato Research Institute (CPRI), Simla, provided valuable information on the seasonal incidence of *M. persicae* which enabled to determine a consistently vector-free period to raise the crop in the plains (Pushkarnath 1976). Similar studies are required for other important species of aphids which unfortunately, has remained a neglected field in this country as mentioned earlier.

MANAGEMENT OF APHID-BORNE DISEASES

Most approaches to control are aimed at eradicating of altering one or more of the primary participants in the transmission process (Vector, virus and host plant) or at preventing their coming together. Breeding plants for immunity, resistance or tolerance to virus infections has proven effective in a number of cases where a particular crop is threatened exclusively or primarily by a single virus.

Knowledge of virus-vector relationship is essential to devise suitable measures against vector-borne diseases. For example, it has already been made clear that transmission of NP viruses does not require feeding by the aphids and just brief probes are enough for transmission. Due to the behaviour of exploratory probings and nondiscriminatory alightment of winged aphids during dispersal, aphids may be instrumental in virus spread to nonhosts. Search for potential vectors in such cases should therefore, not remain limited to aphid species colonising a particular plant species. Such data should be adequately backed up by field observations to ascertain the extent of involvement of a species as a vector in an area at different times of the year. Species which transmit a virus very efficiently under experimental conditions may not necessarily be most important natural vector and some other species may compensate its relative inefficiency by being more numerous and or more active. The bias for few such species is likely to obscure the vision and the species which are really involved may be left out of consideration.

Insecticides, particularly the systemic ones, can sometimes efficiently control the spread of circulative viruses because long acquisition and inoculation feedings are required for transmission. On the other hand, pesticides hardly affect the spread of NP viruses and may rather aggravate the situation by enhancing vector management and more sap sampling.

Mineral and vegetable oils and milk lipids might inhibit NP transmission by modifying the probing and feeding behaviour responsible for transmission. There the physico and electrochemical properties might insulate the sensory transduction system of aphids feeding apparatus and inhibit sap sampling (Simmons *et al.* 1977).

The nonchemical methods of control are becoming increasingly popular due to limitations of pesticides in preventing disease spread, growing problem of aphid resistance and recent awareness of the pollution problems. The control of plant virus disease by cultural practices is not new. As a matter of fact, with the exception of insecticidal applications to reduce aphid populations and the use of herbicides to remove weeds as virus sources, the nonchemical methods have remained the backbone for curbing-borne diseases. The use of disease-free seeds and tubers; removal of weeds, other volunteer crops and crop residues; vector avoidance by crop isolation; growing barrier crops; use of reflective surfaces; manipulating plant distribution, density and field size; suitable adjustment of planting and harvesting dates and breeding resistant cultivars are the major approaches in cultural control.

In India, very useful work has been done by Central Potato Research Institute (CPRI), Simla, by developing "Seed-plot technique" to produce disease-free potato stocks in North Indian plains during aphid free period from October to December (Pushkarnath 1976). The planting should be done by the first week of October in the north-western plains and somewhat later in the eastern plains, using disease-free seed material. The haulms are cut by the first week of January before the advent of adequate number of vector aphids. The tubers are harvested within a month after dehaulming. The adoption of this technique has enabled the CPRI to contribute substantially to the growing demands for disease-free seed potato tubers in this vast country.

In order to prevent virus spread by aphids, integrated programmes have to be developed based on an understanding of the biology and phenology of the vectors and means of perpetuation of the viruses, adopting cultural control measures and minimum application of the proper pesticidal formulations at carefully chosen times.

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NATURAL FOOD RANGE AND FEEDING HABITS OF APHIDOPHAGOUS INSECTS IN NORTH EAST INDIA

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SUMMARY

Natural food range of aphidophagous insects may include aphid and non-aphid foods. All the acceptable aphid foods may not be essential food. Non-aphid food may be other insects or food of plant origin. The common pest aphids have a nearly similar association of aphidophagous insects.

INTRODUCTION

The prey-predator relations, at least in India for aphidophagous insects, have mostly been studied by observing what the aphidophagous insects, happen to be eating at any particular point of time, sometimes only by noting the occurrence of predator and prey together on the same plant (Agarwala and Ghosh 1987) and, therefore, reliability of the list of food of predators of aphids so far recorded from India (till 1984) and summarised in Ghorpade (1981) ; Agarwala *et al.* (1984) and Agarwala and Ghosh, *op cit.* is subject to question. It has been our experience that only a few species of Coccinellidae, Syrphidae and rarely Cecidomyiidae are the potential predators of aphids in North East India and, therefore, it is necessary to establish their natural food range in order to understand the biology and their potency as biocontrol agents.

The natural food range of aphidophagous insects may include aphid and non-aphid food. It is not uncommon among the aphidophagous insects, particularly coccinellids, to feed on alternate or substitute foods when preferred or essential foods are scarce or not adequately available (Hukusima and Itoh 1976) and, therefore, in ascertaining the natural food range the changing habitats of the predator and its feeding habit is to be kept notice of.

This paper present the first sequence of a serial studies and embodies natural food range and feeding habits of 4 species of Coccinellidae, 9 of Syrphidae and 1 species of Cecidomyiidae, all being recognised as potential aphidophagous insects (to be established in papers elsewhere). In the following pages aphid names have not been suffixed by their authors. These may be found in Eastop and Hille Ris Lambers (1976).

MATERIALS AND METHODS

The classical method of ascertaining the natural food range of a predator is to examine the gut contents (foregut) and to compare the prey remnants within the whole specimen of insects or other food from the same community or habitat (Putman 1964). The same method was employed in this study. For this purpose aphids and aphidophagous insects were collected periodically from randomly selected crop and non-crop habitats and examined for their gut contents. In non-aphid seasons, aphidophagous insects were searched in associated habitats and observed for their feeding habit.

RESULTS

COCCINELLIDAE

1. Coccinella septempunctata L.

(a) Accepted Aphid Food — *Aphis fabae, A. gossypii, A. nerii, Brachycaudus helichrysi, Brevicoryne brassicae, Cinara* sp., *Hyadaphis coriandri, Lipaphis erysimi, Macrosiphum rosaeiformis, M. rosae.*

(b) Non-Aphid Food — Not found.

(c) Common Aphid Food — *A. gossypii* on cucumbers, *L. erysimi* on cruciferous crops, *A. nerii* on *Calotropis procera.*

Feeding Habit : Adults and larvae of this lady beetle feed actively when the prey density of *L. erysimi, A. gossypii* and *A. nerii* and other aphid are high on their respective hosts. In the plains and high lands in North East India, the adults and larvae of this coccinellid are quite common in the cropping season but rare to notice in non-cropping periods. Perhaps the last of adults disperse to far areas in search of suitable food and habitat. In the hills, the adults hibernate in soil or subsoil surfaces during winter months and become active in the spring.

2. Coccinella transversalis (Thunberg)

(a) Accepted Aphid Food — *Aphis craccivora, A. gossypii, L. erysimi, Macrosiphoniella kalimpongensis, M. rosaeiformis.*

(b) Non-Aphid Food — None found.

(c) Common Aphid Food — *A. craccivora, L. erysimi.*

Feeding Habit : The adults and larvae essentially feed on aphids when these are available. In absence of aphid food, adults rest on shed trees and feed on some substitutive food which could not be recognised. Reproductive activity is usually restricted to the period of aphid incidence only.

3. Menochilus sexmaculatus (F.)

(a) Accepted Aphid Food — *Aphis citricola, A. craccivora, A. gossypii, A. nerii, Cervaphis schouteniae, Greenideoida ceyloniae, H. coriandri, L. erysimi, M. kalimpongensis, Melanaphis sacchari, Tinocallis kahawaluokalani, Toxoptera aurantii, Uroleucon sonchi.*

(b) Non-Aphid Food — Unidentified scales, mealy bugs, white flies and own eggs.

(c) Common Aphid Food — *A. craccivora* on beans, *A. citricola* on herbaceous weeds, *A. nerii*, *L. erysimi*.

Feeding Habit : This species feeds preferably on aphids when these are available in abundance ; in the absence of aphids, adults switch on to feed in the colonies of scales, mealy bugs, white flies and some other hosts. If nothing is available, then their own eggs are eaten.

4. **Micraspis discolor** (F.)

(a) Accepted Aphid Food — *Aphis citricola*, *A. craccivora*, *L. erysimi*.

(b) Non-Aphid Food — Pollens of *Ageratum conyzoides*, *Brassica campestris*, *Corchorus capsularis*, *Cyperus* sp., *Echinochloa* spp., *Chilomenes odorata*, *Oryza sativa*.

(c) Common Aphid Food — *A. craccivora*, *A. citricola*.

Feeding Habit : The adults although feed on *L. erysimi*, fail to develop on this aphid and do not attain reproductive maturity. All the alternative or non-aphid foods are eaten by adults alone for its maintenance. Non-aphid season is passed off as inactive adults without any oviposition.

CECIDOMYIIDAE

Monobremia rishikeshensis Grover

Larva — *A. citricola* on *Chilomenes odorata* and *A. craccivora* on beans.

Adults — Nectar of herbaceous weeds.

Feeding Habit : Larvae exclusively feed on aphids. It usually attacks its prey by piercing leg joint or some other body-joints. It seems that a toxin is injected which paralyses the aphid as aphids are rapidly immobilised once they have been attacked. Once the prey has been seized and immobilised, the larva settles to feed by extracting the body fluids. It takes a few hours. The shrivelled aphids that have been attacked in this way remain attached to the plants.

SYRPHIDAE

1. **Allograpta javana** (Wiedmann)

(a) Accepted Aphid Food — *Acyrthosiphon pisum*, *A. craccivora*, *G. ceyloniae*, *H. coriandri*, *L. erysimi*, *T. aurantii*.

(b) Common Aphid Food — *A. craccivora*, *L. erysimi*.

2. **Betasyrphus isaaci** (Bhatia)

(a) Accepted Aphid Food — *A. craccivora*, *A. fabae*, *H. coriandri*, *L. erysimi*, *M. kalimpongensis*, *M. rosae*, *U. sonchi*.

(b) Common Aphid Food — *L. erysimi*.

3. **Betasyrphus serarius** (Wiedmann)

(a) Accepted Aphid Food — *Aphis longisetosa*, *L. erysimi*, *U. sonchi*.

(b) Common Aphid Food — *L. erysimi*.

4. **Dideopsis aegrota** (F.)
   - (a) Accepted Aphid Food — *A. craccivora, A. citricola, L. erysimi.*
   - (b) Common Aphid Food — *A. citricola.*
5. **Episyrphus alternans** (Macquart)
   - (a) Accepted Aphid Food — *A. gossypii, H. coriandri, L. erysimi.*
   - (b) Common Aphid Food — *A. gossypii, L. erysimi.*
6. **Episyrphus balteatus** (De Geer)
   - (a) Accepted Aphid Food — *A. craccivora, A. gossypii, L. erysimi, Myzus dycei.*
   - (b) Common Aphid Food — *A. gossypii, L. erysimi.*
7. **Ischiodon scutellaris** (F.)
   - (a) Accepted Aphid Food — *A. citricola, A. craccivora, A. gossypii, L. erysimi, G. ceylonaiae, T. aurantii, T. kahawaluokalani.*
   - (b) Common Aphid Food — *A. citricola, A. craccivora, A. gossypii, L. erysimi, T. aurantii.*
8. **Macrosyrphus confrator** (Wiedmann)
   - (a) Accepted Aphid Food — *A. citricola, A. craccivora, A. fabae, A. pisum, A. gossypii, Brevicoryne brassicae, Ceratovacuna silvestrii, G. ceyloniae, L. erysimi, T. aurantii.*
   - (b) Common Aphid Food — *A. craccivora, L. erysimi.*
9. **Paragus crenatus** (Thomson)
   - (a) Accepted Aphid Food — *A. citricola, A. craccivora, A. gossypii, L. erysimi, T. aurantii.*
   - (b) Common Aphid Food — *A. citricola, A. craccivora.*

Feeding Habit in Syrphid Predators of Aphids : Larvae of all the aforesaid species exclusively feed on aphids and were most active at the heaviest aphid infestation on trees, shrubs or herbs. Most of the syrphid predators seem to be oligo- or polyvoltine species with adults shifting from one feeding site to another. While the adults, for themselves depend on nectar and pollen of the flowering plants in their respective habitats, these oviposit essentially in aphid colonies.

DISCUSSION

Apparently, from the foregone results, it would appear that the potential aphidophagous insects in North East India exhibit polyphagy and feed on widely related aphid species. Most of the recorded aphid prey are common to many of the aphidophagous insects. However, a true food relation may not be really so flexible and overlapping. It has been found that many of these predators have "essential" and "non-essential" or alternative foods and essential foods of any two or more species of aphidophagous insects seldom show same preference at any given time (to be published elsewhere) ; an essential food is one which allows full development of the predator, both of larvae and ovaries (Hodek 1973).

Thus, the natural food range may not be an indicator of predator's true food relations, nonetheless the acceptability of a wider range of food by these predators is an act of adaptation to utilise the available food resources, when essential foods are scarce or not available.

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EFFECT OF SOWING DATE ON APHID INCIDENCE AND YIELD IN SOME VARIETIES OF RAPESEED AND MUSTARD

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SUMMARY

Nine varieties of rapeseed and Mustard viz , Ys–Pb–24, Ys–B–9, Yss–8 of yellow sarson group, BSH-1, BS-113, Pusa Kalyani of brown sarson group, Sangam of toria group RH–30 and Pusa bold of raya group, were tested for aphid incidence and yield by sowing their seed at 10 days interval on 5th Oct., 15th Oct., 25th Oct., 5th Nov. and 15th Nov. during 1978-79 and 1979–80 crop season. The experiments were conducted at the farm of Indian Agricultural Research Institute, New Delhi. It was found that delayed sowings exposed the crop to a higher aphid infestation. Crop sown by the middle of October escaped the severity of aphid attack since the peak infestation is reached after the crucial growing and flowering period is over resulting in higher yield irrespective of varietal differences.

INTRODUCTION

Rapseed and mustard are second important oilseed crops grown in the country. These are prone to the attack of a number of insect pests (Rai 1976) amongst which mustard aphid, *Lipaphis erysimi* (Kalt.) is the most serious pest and a limiting factor in the realization of full yield potential of a genotype. A number of insecticides are recommended for its control. However, cultural control of the pest is another important component of an integrated pest management strategy in order to minimize the pest menace and the hazards accruing from insecticidal control. The present investigations were therefore taken up to find out the response of a few genotypes of *Brassica* cultivars sown on different dates to aphid infestation vis-a-vis yield.

MATERIALS AND METHODS

The investigations were carried out at the experimental farm of the Indian Agricultural Research Institute, New Delhi for two consequtive years, 1978–79 and 1979–80. The experiments were conducted in a split-plot design, replicated thrice. Nine varieties viz., Ys–Pb–24, Ys–B–9, Yss–8 (*Brassica campestris* var. yellow sarson), BSH–1, BS–113, Pusa Kalyani (*B. campestris* var. brown sarson), Sangam (*B. campestris* var. toria) RH–30 and Pusa bold (*B. juncea*, var. raya) constituted the main treatments and five dates sowings *i.e.*, 5th Cct. (D_1), 15th Oct. (D_2), 25th Oct. (D_3), 5th Nov. (D_4) and 15th Nov. (D_5), the sub-treatments. Each sub-treatment consisted of a plot size of 1·8 m × 3·0 m with three rows 60 cm apart. Plant to plant distance was kept at 25 cm. Recommended agronomic practices were followed in raising the crop. Aphid incidence on each crop variety in each date of sowing was recorded on 12 plants, 4 from each row in terms of aphid infestations index. (Prasad and Phadke 1980). Such observations were taken on every 60, 80, 100 and 120 days after each sowing date or till the aphids appeared on the crop since in last three sowings dates (D_3—D_5) no aphids were seen after 120 days.

RESULTS AND DISCUSSION

The results on aphid incidence for both the years are given in Tables 1 and 2. The tables show aphid incidence on the crop varieties at the same crop age in different sowings. The data show that with the delay in sowings, there was a higher aphid infestation on all the varieties. Amongs the varieties, aphid infestation index was relatively more on yellow sarson and toria varieties than on brown sarson and raya varieties. The differences in aphid infestation between the dates and between the varieties were significant except at 120 days. Aphid infestation between the first two sowing dates *i.e.* D_1 and D_2 was not significant, though there were significant differences in aphid infestation between the varieties. The results further show that peak infestation in D_1 and D_2 is reached after 120 days, in D_3 and D_4 after 100 days and in D_5 after only 80 days of crop age. This shows that delayed sowings made the plants to suffer from higher injury at a younger crop stage.

This effect is further seen on the basis of seed yield obtained in each variety, when sown on different dates (Table 3). It is found that, in both the years, maximum yield was obtained from six varieties in D_2 and a further delay resulted in its decline. Only two varieties *i.e.* Ys–Pb–24 and Ys–B–9 of yellow sarson and sangam of toria group gave maximum yield in D_1 in both the years. The differences in yield were found to be significant between dates of sowings, varieties and their interaction. High seed yield obtained in earlier sowing dates (D_1 and D_2) suggests that early sown crop escaped severity of aphid onslaught at its crucial period of flowering, since peak infestation is reached by the time flowering is over and most of the pods have been formed. With the delay in sowing date, growing stage and flowering period coincided with the peak period of infestation resulting in yield decline (Bhattacharjee 1961 ; Tripathi and Singh 1969 ; Kundu and Pant 1967, 1968 ; Singh *et al.* 1984). The results, thus, show that irrespective of the variety, sowing should be done by the middle of October to minimize the aphid attack and obtain maximum yield. However, the three varieties, particularly sangam of toria group should be tested further for its response, if sown still earlier.

TABLE 1. Mean aphid infestation index in relation to crop age in different dates of sowings 1978–79.

	CROP AGE (DAYS)											
	60						80					
Sl.No. Variety	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
1. Ys–Pb–24	26·0	15·7	35·3	32·7	44·3	30·8	29·0	46·0	34·3	34·3	58·3	43·8
2. Ys–B–9	30·0	21·3	26·3	29·3	32·0	27·8	41·0	35·3	31·0	33·0	52·3	38·5
3. Yss–8	9·0	9·7	21·7	24·3	50·7	23·1	13·7	23·7	30·0	36·7	59·7	17·9
4. BSH–1	16·0	9·0	16·3	19·3	24·0	9·4	19·3	25·7	21·7	33·7	44·3	28·9
5. BS–113	11·0	7·7	13·3	16·0	23·0	14·2	22·7	19·7	17·3	28·3	34·7	24·5
6. Pusa Kalyani	5·3	6·7	13·7	14·0	27·3	13·4	16·0	22·0	17·3	29·7	33·0	23·6
7. Sangam	29·7	19·0	30·3	27.7	31·3	27·6	48·3	36·7	41·3	38·7	49·0	42·8
8. RH–30	11·7	7·3	14·3	18·7	22·0	14·8	21·0	21·0	23·3	30·0	31·0	25·3
9. Pusa bold	9·7	11·0	13·7	19·0	25·7	15·8	27·7	25·0	22·3	33·3	34·0	28·5
Mean	16·5	11·9	20·5	22·3	31·5	19·7	26·5	28·3	28·4	32·8	41·0	30·4
CD at 5% for Dates (D)	4·17						4·04					
,, ,, Varieties (V)	3·12						4·54					
,, ,, D×V	6·98						9·99					

	100					120		
Sl.No. Variety	D_1	D_2	D_3	D_4	Mean	D_1	D_2	Mean
1. Ys–Pb–24	39·0	54·3	52·3	60·0	51·4	54·0	60·0	57·0
2. Ys–B–9	42·7	51·3	52·3	60·0	51·6	54·7	56·3	55·5
3. Yss–8	42·7	53·3	56·3	59·3	52·9	47·7	58·3	53·0
4. BSH–1	33·7	37·7	38·7	39·7	37·4	40·3	40·3	40·3
5. BS–113	33·3	37·7	39·7	41·0	37·9	35·3	42·7	39·0
6. Pusa Kalyani	33·3	35·3	35·3	37·7	35·4	34·3	37·3	35·8
7. Sangam	58·0	58·0	60·0	57·8	58·7	58·7	60·0	59·4
8. RH–30	27·0	37·7	35·7	37·3	34·4	35·7	38·3	37·0
9. Pusa bold	31·7	39·0	37·7	39·0	36·8	32·3	42·3	37·3
Mean	37·9	44·9	48·2	44·8	44·0	43·7	48·4	46·0
CD at 5% for Dates (D)	1·70					N.S.		
,, ,, Varieties (V)	2·99					4·12		
,, ,, D×V	5·99					N.S.		

TABLE 2. Mean aphid infestation index in relation to crop age in different dates of sowings 1979–80.

		CROP AGE (DAYS)											
		60						80					
Sl.No.	Variety	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
1.	Ys-Pb-24	16·7	31·0	43·0	34·0	44·7	33·9	25·3	54·0	44·3	53·0	53·0	45·0
2.	Ys-B-9	18·3	30·3	38·7	33·0	41·7	32·4	36·7	43·0	47·0	46·3	53·7	45·3
3.	Yss-8	14·7	30·7	43·0	23·7	41·3	30·7	32·3	52·0	48·3	39·7	51·0	44·7
4.	BSH-1	12·3	21·0	26·7	25·3	31·3	23·3	26·7	36·0	36·3	31·3	36·0	33·3
5.	BS-113	11·7	14·3	26·0	20·3	27·7	20·0	28·0	33·2	34·7	33·7	37·3	33·4
6.	Pusa Kalyani	12·7	14·0	25·0	17·3	28·0	19·4	27·3	33·7	33·3	32·0	37·3	32·7
7.	Sangam	25·7	35·3	43·7	36·0	37·7	35·9	50·0	53·7	47·0	51·7	56·3	51·7
8.	RH-30	10·0	17·0	25·3	19·3	27·0	19·7	21·0	32·3	33·7	28·7	33·7	29·8
9.	Pusa bold	13·0	16·3	32·3	23·0	34·3	23·8	28·7	35·7	35·7	36·7	39·0	35·1
	Mean	15·1	23·3	33·7	25·8	34·9	26·6	30·7	41·5	39·6	39·2	44·2	39·4
C.D. at 5% for Dates (D)		5·31						7·24					
,, ,, Varieties(V)		3·83						3·01					
,, ,, D×Y		N.S.						6·75					

		100					120		
Sl.No.	Variety	D_1	D_2	D_3	D_4	Mean	D_1	D_2	Mean
1.	Ys-Pb-24	49·3	52·3	56·7	52·0	52·6	58·3	59·7	59·0
2.	Ys-B-9	40·7	38·3	38·3	35·3	38·1	51·3	49·0	50·2
3.	Yss-8	24·3	38·0	40·7	49·7	38·2	39·3	41·0	40·2
4.	BSH-1	24·3	29·0	31·0	36·0	30·1	40·3	36·3	38·3
5.	BS-113	26·3	28·0	31·0	34·0	29·8	36·0	28·0	32·0
6.	Pusa Kalyani	23·3	33·0	32·3	34·3	30·7	34·7	29·3	32·0
7.	Sangam	49·3	50·3	53·3	52·3	51·3	57·3	60·0	58·7
8.	RH-30	31·0	32·0	35·0	35·0	33·3	36·0	29·7	32·8
9.	Pusa bold	34·0	31·3	31·3	32·7	32·3	36·0	27·0	31·5
	Mean	33·6	36·9	38·8	40·2	37·4	43·3	40·0	41·6
C.D. at 5% for Dates (D)		2·28					N.S.		
,, ,, Varieties (V)		5·20					2·09		
,, ,, D×Y		N.S.					N.S.		

TABLE 3. Mean yield Q/ha from the different varieties of rapeseed and mustard.

		Yield Q/ha											
		1978–79						1979–80					
		Dates of Sowing						Dates of Sowing					
Sl.No.	Variety	D_1	D_2	D_3	D_4	D_5	Mean	D_1	D_2	D_3	D_4	D_5	Mean
1.	Ys–Pb-24	6·1	5·0	3·9	1·7	1·1	3·6	3·1	2·2	1·2	0·5	0·3	1·5
2.	Ys–B-9	4·3	3·2	4·3	3·8	0·6	3·3	2·6	1·9	1·0	0·3	0·2	1·1
3.	Yss–8	3·2	4·6	2·8	0·8	0·4	2·3	3·1	3·4	2·1	1·1	0·3	2·0
4.	BSH–1	6·5	6·9	6·2	7·0	1·8	5·7	4·7	6·0	4·7	2·8	0·9	3·9
5.	BS–113	15·0	17·1	13·8	13·9	5·9	13·1	11·3	12·4	8·0	4·1	1·4	7·4
6.	Pusa Kalyani	13·3	15·5	13·7	13·1	9·0	12·9	11·1	12·3	9·1	4·5	0·8	7·6
7.	Sangam	5·2	3·1	2·6	2·7	1·3	3·0	2·9	2·4	1·5	0·6	0·0	1·5
8.	RH–30	10·4	16·0	14·1	14·5	8·4	12·7	18·0	21·2	15·4	9·0	2·3	13·2
9.	Pusa bold	9·0	17·7	14·2	13·3	6·4	12·1	14·3	15·7	10·1	4·7	2·0	9·3
	Mean	8·1	9·9	8·4	7·9	3·9	7·6	7·9	8·6	5·6	3·1	0·9	5·3
C.D. 5% for Dates (D)		0·61						1·15					
„ „ Varieties (V)		1·72						1·55					
„ „ D×V		3·82						3·54					

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CHROMOSOMAL STUDIES IN FOUR SPECIES OF INDIAN APHIDS (HOMOPTERA : APHIDIDAE)

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SUMMARY

Mitotic chromosomes of 4 species of aphids (*Aphis citricola*, *Aphis punicae*, *Coloradoa rufomaculata* and *Pentalonia nigronervosa*) are being reported here. Three species (*A. citricola*, *A. punicae* and *C. rufomaculata*) have a diploid number of 8 chromosomes while *P. nigronervosa* has diploid counts of 14. Relative sizes of chromosomes of species with 8 chromosomes are found to be almost identical while their absolute sizes show some variation. In addition to fragmentation/fusion role of loss/gain of chromatin material during speciation in aphids has also been postulated.

INTRODUCTION

Aphids are of great cytological interest chiefly due to their thelytoky mode of reproduction, holokinetic chromosomes and intraspecific chromosomal variation. Till date only a little more than 17% of the total number of described aphids are karyologically known (Kurl 1986). It is now understood that the karyological data may be of some help in solving taxonomical problems of this group. But in order to get a comprehensive picture of aphid cytotaxonomy a large number of species have to be cytologically analysed. This prompted us to undertake the present investigation.

Out of the four species dealt here three are being reported for the first time while *Aphis citricola* was studied previously by Kurl and Chauhan (1985).

MATERIALS AND METHODS

Early embryos of apterous viviparous females of four species of aphids (Table 1) were dissected out. Embryos were incubated in 0·4% Kcl containing 0·05% colchicine for about 15 to 20 minutes and fixed in a drop of 50% acetic acid for a minute or two prior to squashing. After removal of cover slips in 50% alcohol, the slides were dehydrated, stained in 3% Giemsa and air-dried. Either the slides were observed as such or mounted in DPX.

OBSERVATIONS

Mitosis :

All the four species dealt in this study show orthodox mitotic behaviour of their chromosomes.

The resting nucleus of these species does not show a heteropycnotic sex chromatin. Prophase is characterised by thread like chromosomes forming an irregular net work. Darkly stained short, thick and condensed chromosomes make their appearance during metaphase (Figs. 1–4). On reaching anaphase the separating chromatids form two parallel sheet-like masses which start moving towards two opposite poles. In telophase these two masses reach their respective poles and become spherical. Chromosomes of none of these species exhibit primary constriction.

Chromosome number and metrical data :

Out of four species of this study *A. citricola*, *A. punicae* and *C. rufomaculata* have 8 while *P. nigronervosa* has 14 chromosomes in their respective diploid complements (Table 1 and Figs. 1–4).

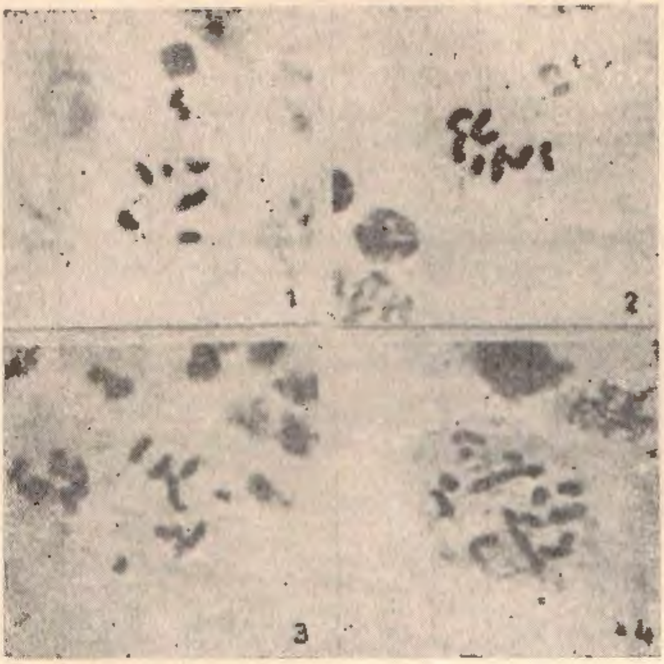
TABLE 1. Aphids, host plants, date and place of collection and their diploid chromosome numbers.

Species	Host Plant	Date of Collection	Place of Collection	Chromosome number (2n)
Aphis citricola van der Goot	*Sida cordifolia*	Aug., 1986	Chatrapur, Orissa	8
Aphis punicae Passerini	*Prunus* sp.	Nov., 1986	-do-	8
Coloradoa rufomaculata Wilson	*Chrysanthemum coronarium*	Sept., 1986	-do-	8
Pentalonia nigronervosa Coquerel	*Musa* sp.	Dec., 1986	-do-	14

The absolute lengths of chromosomes range from 4·56 μ to 2·58 μ in *A. citricola*, from 3·61 μ to 1·77 μ in *A. punicae*, from 5·39 μ to 2·47 μ in *C. rufomaculata* and from 6·51 μ to 1·3 μ in *P. nigronervosa* (Table 2). In all these species except in *P. nigronervosa* the chromosomes are observed to be gradually seriated. In the latter species, however, there is drastic reduction in size between 1st and 2nd chromosomes. On comparison the relative lengths of chromosomes of *A. citricola*, *A. punicae* and *C. rufomaculata* seem almost identical (Table 2). But all these four species show considerable variation in their TCL. On the whole variation among the species with a diploid count of 8 chromosomes do not seem very remarkable as well as statistically significant.

DISCUSSION

Genus *Aphis* is known cytologically by about 58 species (Kurl 1986). All but 7 species of this genus have 8 as their diploid number. *A. oenotherae* and *A. rosae* have 2n=10 (Stevens 1905, 1910) and *A. ferinosa* has a diploid number of 6 chromosomes (Stevens 1906, 1909). Our study further substantiates the view that 2n=8 is the basic diploid number of genus *Aphis*. Deviations from this basic number might have resulted through structural rearrangements



Figs. 1-4. Mitotic metaphases of four species of aphids. 1. metaphase of *A. citricola* (2n=8), 2. metaphase of *A. punicae* (2n=8), 3. metaphase of *C. rufomaculata* (2n=8) and 4. metaphase of *P. nigronervosa* (2n=14).

like fragmentations and fusions (Kurl and Misra 1979 ; Khuda-Bukhsh 1980 ; Khuda-Bukhsh and Pal 1985). Karyotypic evolution through fragmentation/fusion has also been suggested for genera such as *Myzus* (Khuda-Bukhsh and Pal 1986 a), *Macrosiphum* (Khuda-Bukhsh 1980), *Rhopalosiphum* (Kurl and Misra 1979), *Tinocollis* (Datta and Khuda-Bakhsh 1980), *Macrosiphoniella* and *Uroleucon* (Khuda-Bukhsh and Pal 1986 b). No conspicuous size difference was observed between the chromosomes of *Aphis* species in this study (Table 2). Hence mutual exchange by fragmentation/fusion mechanism as suggested by Khuda-Bukhsh (1982) and Khuda-Bukhsh and Pal (1985) for genus *Aphis*, does not seem to have taken place in these congeneric species. However the total length of haploid set of 2 species of *Aphis* exhibit considerable variation between them which leads us to presume that loss or gain of chromatin material might have played a role during karyotypic evolution in them.

No species from the genera *Coloradoa* and *Pentalonia* is cytologically known so far.

While chromosomes of *C. rufomaculata* (2n=8) are almost identical in their relative lengths with those of *Aphis* species they exhibit comparatively higher absolute lengths (Table 2). Whether this increase in absolute size is real

TABLE 2. Measurements of chromosomes of four species of aphids.

Species	Chromosomes in haploid set													
	1		2		3		4		5		6		7	
	AL	RL	AL	RL	AL	RL	AL	RL	AL	RL	AL	RL	AL	RL
Aphis citricola	4·56 ±0·76	31·86	3·91 ±0·61	27·32	3·38 ±0·71	23·50	2·58 ±0·39	17·28	—	—	—	—	—	—
Aphis punicae	3·61 ±0·71	33·08	2·91 ±0·56	26·69	2·61 ±0·55	23·79	1·77 ±0·44	16·30	—	—	—	—	—	—
Coloradoa rufomaculata	5·39 ±0·98	33·38	4·43 ±0·58	27·69	3·77 ±0·49	23·63	2·47 ±0·52	15·33	—	—	—	—	—	—
Pentalonia nigronervosa	6·51 ±1·00	29·79	3·78 ±0·69	17·23	3·25 ±0·26	14·95	2·65 ±0·32	12·55	2·34 ±0·28	10·37	1·99 ±0·18	9·15	1·30 ±0·34	5·88

AL = Absolute length (μm)

RL = Relative percentage length.

or apparent, remains to be proven. Sun and Robinson (1966) reported that species with lower chromosome numbers have larger chromosomes and those with higher numbers have smaller chromosomes. But in our study *Pentalonia nigronervosa* not only has a higher diploid number (2n=14) but also has many chromosomes as large as those of species with 2n=8. It has also the highest TCL in our study. Thus it may be postulated that in addition to fragmentation/fusion evolutionary addition/loss of chromatin material might have also been instrumental in bringing about variation in chromosome number in Aphididae.

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COURTSHIP, MATING AND OVIPOSITION BEHAVIOUR OF *DIAERETIELLA RAPAE* (M'Intosh) (HYMENOPTERA : APHIDIIDAE), A PRIMARY PARASITOID OF *LIPAPHIS ERYSIMI* (Kalt.) (HOMOPTERA : APHIDIDAE)

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SUMMARY

Diaeretiella rapae is an aphidiid endoparasitoid of *Lipaphis erysimi*. Some aspects of its reproductive behaviour were studied. Copulation starts short after the emergence and the period between emergence and mating is of 5 to 60 minutes. It comprises two phases, (i) Preparatory phase, (ii) Courtship resulting in mating. The length of mating varies from 30 to 120 seconds while the actual mating lasts for 20±5 seconds. The oviposition also comprises two phases, (i) Preoviposition, (ii) Oviposition. The preoviposition period lasts for about 10 to 90 minutes from emergence with an average of 42 minutes and virgin takes 48 minutes. The length of oviposition is observed 40 to 80 seconds.

INTRODUCTION

Courtship, mating and oviposition behaviour in the aphidiid parasitoids involve a complex of actions as in several other groups of insects. The courtship and mating behaviour might be acting as an ethological barrier between closely related sympatric species (Assem and Povel 1973 ; Evans and Mathews 1976). Thus, the whole of the life of a parasitoid mainly depends on these two behaviours. Out of 18 factors of Stary (1970) on parasitic effectiveness, these two factors have very significant role in their life.

D. rapae (M'Intosh) is a primary parasitoid of various aphid species. In India, it parasitises the *L. erysimi*, which in turn is a serious pest of cruciferous crop. The parasitoid considerably checks the out break of the aphid on the radish crop in North-Western U. P. (Dhiman and Kumar 1983, 1986 a ; Kumar 1987). On the Indian sub-continent, no detailed studies have been made so far on the ethological behaviour of this parasitoid ; therefore, to fill this gap the present studies were undertaken.

MATERIALS AND METHODS

The courtship and mating behaviour of *D. rapae* was studied at Saharanpur (U. P.) from 1985 to 1987 in the peak season, March to May. For the study,

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the original parasitoids were taken from the laboratory reared stock and the rearing was done on its host *L. erysimi* in a small wooden wire gauze cage (30 × 30 × 30 cm) by providing 30 to 40% honey solution as a feeding diet and a cotton swab dipped in water for maintaining necessary relative humidity. In case, the parasitoid refused the feeding on honey solution then the food was replaced by pure honey. The host aphids were also taken from the laboratory reared culture of caged potted radish plants. Preference of radish plants over mustard plants as a food of aphid host was described elsewhere (Dhiman and Kumar 1986 a, 1987).

The freshly emerged non-mated males and virgin females were taken from the culture and released into the small glass petridish and covered by thin glass plate by keeping the muslin cloth on the margin of petridish for aeration. For the study of oviposition, same techniques were followed as in aforesaid experiment. Fully fed, mated and virgin females were taken from the same culture. Both the phenomenon were observed with the aid of sterioscopic bionocular.

OBSERVATION AND DISCUSSION

1. Courtship and Mating—D. rapae starts copulation shortly after emergence from mummies. The period between emergence and mating varies from 5 to 60 minutes. The whole of this phenomenon comprises two steps, viz., preparatory phase and courtship resulting in mating.

(*i*) *Preparatory phase*—In this phase, the parasitoid after the emergence from the mummies, dry and cleans its body parts, viz., antennae, mouth parts, wings, abdomen and genitalia, with the help of pretarsi of all the legs which possess spur and spines. When the sexes were kept together in the same petridish, after the end of preparatory phase, the male get excited by the presence of female and starts vibrating its wings in the air within a second even without touching the female. During the excitement, the male shows great activities. First, he raises his right antenna, moves it upward and downward, then the left one and acts similarly. At this time, the female remains inactive. She remains busy in preening her body, moving antennae slowly and walks for a while. As the time lapse, the male becomes more excited, runs continuously and moves antennae and wings rapidly, as said above. He approaches the female, contacts her first by touching antennae or other body parts with the help of his antennae according to the position of female. In this phenomenon, female remains passive again. The excited male wants to mount on her back quickly, but the female which is not excited totally refuse his response by walking from one place to other or taking short flight. In some cases, she also kicks to keep him away. Even at this, the male, again tries to tap and follow her by taking short flight or running. In this way, male repeates the same phenomenon several times which he does previously. Thus, this sequence of the events continues till the female is excited, gradually. In this way, the male follows female. An almost similar behaviour has also been observed by Schlinger and Hall (1960, 1961), Das and Chakrabarti (1986). However, Singh and Sinha (1982) remained silent about this in the case of *Trioxys indicus*. At the same time, the female rubs the posterior most part of the abdomen, viz., genitalia with the help of pretarsus of her hind legs and bends the abdomen downwards. By this act she tries to disaminate the sexual phenomenon to get ready the male for mating. Schwinck (1954, 1955, 1958) said that sexual odour is effective to attract the male only from a short distance. Later on, Amoore (1964) described the stero-chemical theory of olfaction which is discussed in detail by Amoore *et al.* (1964). No detailed observations have been carried on this aspect and it needs further investigations.

At last, when female is excited and gets ready for mating ; she gives positive signals by sitting quietly, fold her legs slightly, spread her wings horizontally over the abdomen. This characteristic posture is adopted by female only to facilitate the male to mount on her back. All these characters indicate that she is highly excited and ready to mate. When both the sexes become ready to mate, then the male mounts on her back quickly for mating.

(*ii*) *Mating*—During mating, the male taps her head and thorax with his antennae. Frequently, the male moves his antennae rapidly upward and downward and grasp the female firmly with the help of fore and middle legs, holding middle and hind legs of the female. The fore legs of female and hind legs of male remain free. Simultaneously, the male places his hind legs against the posterior abdominal part of the female which result the abdominal segment of the male to bend downward and forward in such a way that his genitalia make contact with that of female. As he touches the female genitalia, male insert his penis into the female genitalia through the abdominal curvature as said above. He gives the abdominal strokes and seminate the sperms inside the female. During the copulation, the male vibrates his antennae in air slowly and keeps his wings directed somewhat vertical posteriorly.

In *D. rapae*, mating starts within 5 to 60 minutes after the emergence from the host mummies. The parasitoid takes some time for settlement. However, Das and Chakrabarti (1986) observed $39 \cdot 10 \pm 5 \cdot 82$ as an average premating period in *Kashimiria aphidis*. Many authors observed that mating occurs almost immediately or soon after the emergence (MacGill 1923 ; Lutzhetzski 1960 ; Hafez 1961 ; Schlinger and Hall 1960, 1961 ; Subba Rao and Sharma 1962 ; Atwal *et al.* 1969 ; Singh and Sinha 1982 ; Kumar 1987). However, Vevai (1942), Arthur (1944) and Sekhar (1957) reported that mating does not occur in the first hour just after emergence. The length of mating in *D. rapae* is 30 to 120 seconds while the actual mating lasts for 20 ± 5 seconds. But Atwal *et al.* (1969) mentioned this period as 25 to 85 seconds. However, Stary (1970) said that it is different in individual species.

After the completion of successful mating, the male dislodges from female and fly away to other place without showing any response to her. After some time, if the same male wanted to mate with her again, she totally refuses his response. The same behaviour is repeated when nonmated freshly emerged male supplied to her. Thus, the female *D. rapae* mates once in her life time, though, the male can mate with several females. However, Arthur (1944) observed in *Aphidius granarius* that the same female may be mated more than once with the same or different males. After mating, she remains busy to clean her body parts, take rest for a while and starts to walk on petridish in search of host for oviposition. If we supply her second and third instars nymphs of *L. erysimi* in the petridish, she starts oviposition even without wasting time. Some observations were also noted on the mating capacity of male *D. rapae*. On the supply of 30 to 40% honey solution as a food and virgin females in the petridish, he can mate upto 4 to 6 times, depending upon the age of the parasitoid. After each mating, he spents sometime by taking rest and food or cleaning his body parts ; perhaps, to get freshness or to restore energy for next mating which is exhausted in the previous mating. The effect of temperature and food on the number of matings was also observed by Tremblay (1964). According to him, the food is directly corelated with the number of matings. *D. rapae* avoids mating during the hot sun, when the temperature remains above 32°C in the field.

2. *Oviposition*—Like that of mating, the oviposition has been studied in two parts.

(*i*) *Pre-oviposition*—After the end of mating, the female *D. rapae* cleans her different body parts mainly ovipositor and ovipositor sheaths as stated in aforesaid experiment. On supply of lower nymphal instars, *i.e.*, I, II and III, of the host *L. erysimi* on a piece of radish leaf to her in the petridish, she became activated and walked in the colony of the aphids and sometime she took flight inside the petridish. Her wings folded on the back and antennae move in every direction. Now she came close to the aphid colony by walking or short flight and started search of an appropriate host for oviposition and for this purpose she uses her antennae in tapping the host. First she touches her antennae to ensure whether the host is suitable or not for oviposition. If the host is unsuitable, she refuses and moves herself for suitable ones. During tapping, the antennae stand erect parallel to the body and moves slowly.

Likewise, the virgin females also exhibit the same behaviour with slight difference. She takes sometime in the activation for oviposition within the host colony. The pre-oviposition period from emergence to oviposition lasts for about 10 to 90 minutes with an average of 42 minutes and virgin female takes an average of 48 minutes. Das and Chakrabarti (1986) observed this period of $2{\cdot}00 \pm 1{\cdot}22$ minutes in *Kashimiria aphidis* after mating to onset the act of oviposition and virgin female took about $24{\cdot}63 \pm 7{\cdot}83$ minutes. However, some authors did not observe any difference between virgin and mated females on the onset of oviposition in their respective insects (Vevai 1942; Subba Rao and Sharma 1962; Tremblay 1964). But Sekhar (1957) observed in *Praon aquti* that female starts oviposition after 2 to 70 minutes of mating while the virgin female starts oviposition after 2 hours of emergence. Stary (1970) said that mating can stimulate the oviposition ability, though the presence of host, temperature and humidity also play very significant role to influence the phenomenon.

(ii) *Oviposition*—After the selection of suitable host aphid, the female stands on her legs, the abdomen bends anteriorly just beneath the thorax and reaches upto its head between the legs. The retractile ovipositors and ovipositor sheath are pushed forward rapidly and inserted within the abdomen of the host and the eggs are deposited. Oviposition site has already been described by Dhiman and Kumar (1986 b). In most of the cases, the ovipositing female remains some distance away from the host and contacts it only with ovipositor. During the oviposition, the anterior end of the flagellum of antennae hold the aphid body and her wings are held over the abdomen horizontally.

The female parasitoid finds her host aphids within a few minutes. Normally, so many failure attempts are done prior to an actual oviposition. The length of the oviposition is about 40 to 80 seconds. It varies among the different species of aphidiid parasitoid from 00·02 to 3·00 minutes (Vidano 1959; Schlinger and Hall 1961; Stary 1962; Tremblay 1964). In the opinion of Stary (1970), the length of oviposition can be influenced directly by the age of the female and the size of the host. Our observations also support his view.

After the deposition of eggs, the female contract her ovipositor and ovipositor sheath from the host body immediately and replace the abdomen and wings in the normal position. After cleaning the ovipositor, she is again ready to oviposit the eggs into another host. During the exposure time, she deposits the eggs in succession. This act is interupted by a short interval of rest. After 1 or 2 hours, however, the rate of oviposition decreases with an increase in the number of successive oviposition. This is perhaps due to exhaustion as well as less number of eggs present in the female. In the resting period, the female sits quietly and walks slowly around the host colony or clean her ovipositor, body parts, keeps antennae vertical and moves slowly, wings remain in normal position. This phase of insect is termed as rest by Stary (1970). Few hours may lapse before the female parasitoid tries to oviposit again. In the second act, she deposits a small number of eggs usually within longer intervals. After some time, she goes to hide for one or more hours. In field, she may hide in appropriate site, i.e., under surface of leaves. This period of inactivity is spent by her as a rest, as stated above. Towards the end of oviposition, the female exhibits indifference to the host, flying and walking to other place far from the host colonies. During the field study it was observed that the female starts oviposition in the early morning and late evening because the high temperature reduces the rate of fecundity. She avoids hot sun during oviposition and hide herself under the leaves of the plants.

Regarding the host selection and discrimination behaviour of the *D. rapae*, Dhiman and Kumar (1987) said that the female detects its host by macro-orientation. It prefers the lower nymphal instars for oviposition then the higher and the alate stage of the host is also parasitized.

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HAEMOCYTES OF *RHOPALOSIPHUM NYMPHAEAE* (L.) (APHIDIDAE : HOMOPTERA)

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SUMMARY

Five types of haemocytes are found in the haemolymph of *Rhopalosiphum nymphaeae* (L.) viz., prohaemocytes, plasmatocytes, podocytes, granular haemocytes and adipohaemocytes. In the first three nymphal stages, the haemolymph contains only prohaemocytes and plasmatocytes, and in the 4th instar, granular haemocytes are found in addition to the former two types. In the 1st nymphal instar, prohaemocytes percentage is the highest (as high as 98%). Podocytes and adipohaemocytes are exclusively found in adult forms.

INTRODUCTION

Although all insects have cells comparable to the leucocytes of other animals, none have cells truely comparable to the vertebrate erythrocytes (Jones 1962). Some entomologists believe that the different types of haemocytes which have been described in insects represent only stages in the development of a final end-type. But the coexistence of many diverse cells within the haemolymph of some adults show that this old idea is not true. The seven most commonly encountered types are prohaemocytes, plasmatocytes, granular haemocytes, cystocytes or coagulocytes, adipohaemocytes, spherule cells and oenocytoids (Gupta 1979). Three types of haemocytes which occur relatively infrequently or not at all include podocytes, vermiform cells and granulocytophagous cells.

Although our knowledge on aphid hemocytes is very much restricted, of late, Boiteau and Perron (1976) have described the haemocytes of the potato aphid, *Macrosiphum euphorbiae* (Thomas). Behura and Dash (1969) of the maize aphid, *Rhopalosiphum maidis* (Fitch) and Behura and Bohidar (1983) of four species viz., *Lipaphis erysimi* (Kalt.), *Pentalonia nigronervosa* Coq., *Macrosiphoniella sanborni* (Gill.) and *Aphis craccivora* Koch. In the present investigation an attempt has been made to report the types of haemocytes of the lotus aphid, *Rhopalosiphum nymphaeae* (L.).

MATERIALS AND METHODS

Adult apterous and alate virginoparae of *R. nymphaeae* were collected from lotus leaves (*Nelumbium speciosum*) during winter. The blood cells of both adults and nymphs were studied following the technique of Sarkaria *et al.*

(1951). As far as possible the terminology used by Romoser (1973) is adopted in the present description. The investigation was carried out in the laboratory at the temperature of 27±1°C and 65±2% mean relative humidity.

RESULTS AND DISCUSSION

The haemocytes of *R. nymphaeae* have been grouped into five types as : Prohaemocytes, plasmatocytes, podocytes, granular haemocytes and adipohaemocytes (Fig. 1) (Table 1).

Prohaemocytes : Most of these cells are small, rounded or ovoid in shape having centrally located intensily basophilic, large round to oval nucleus with granular chromatin material. The nucleus in most of these cells occupies the entire cell leaving only scanty cytoplasm at the periphery which is homogenous and basophilic. There is not much variation in the size of different shaped haemocytes.

Plasmatocytes : These cells are generally extremely pleomorphic and may be round ovoid, elongated, spindle shaped, stellate or irregular but the

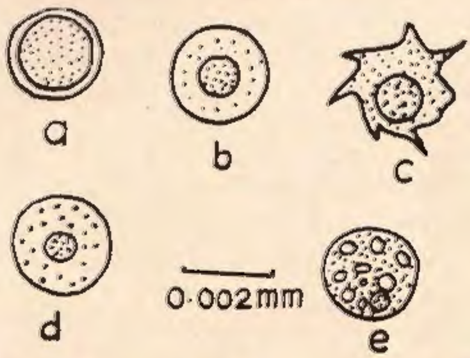

Fig. 1. Types of haemocytes in *Rhopalosiphum nymphaeae* (L.). a. Prohaemocyte, b. Plasmatocyte, c. Podocyte, d. Grannular haemocyte, e. Adipohaemocyte.

TABLE I. Size of the haemocyte types and their respective nuclei (in μ) of adult apterous virginoparae of *R. nymphaeae* (L.) at 25 ± 2°C and 68 ± 2% R. H.

	Diameter of cell	Mean	Diameter of nuclei	Mean
Prohaemocytes	0·8 — 2·4	2·0	0·6 — 1·9	1·7
Plasmatocytes	1·7 — 2·8	2·5	0·6 — 1·2	0·8
Podocytes	2·4 — 2·8	2·6	0·8 — 1·6	1·2
Granular haemocytes	2·0 — 3·0	2·6	0·4 — 0·8	0·6
Adipohaemocytes	1·8 — 2·8	2·2	0·4 — 0·6	0·5

round and ovoid shapes are most common. These cells usually have a centrally placed nucleus which is strongly basophilic and abundant eosinophilic cytoplasm, generally with only a few round or avoid inclusions. They may be subdivided into microplasmatocytes with small nuclei and macroplasmatocytes with large nuclei. They are few in number in first instar nymph.

Podocytes : These cells are found in very small number. They are large and irregular in shape giving our 3–8 cytoplasmic projections or pseudopodia. They are arranged around a very large rounded centrally placed nucleus. These cells resemble the lamellate plasmatocytes described by Gupta (1979).

Granular haemocytes : These cells are typically larger than the prohaemocytes. Most of these cells are rounded to avoid and have many sharply outlined small granular inclusions, of uniform size and basophilic nature in an abundant cytoplasm. They normally have one, small round or oval centrally placed nucleus which is also basophilic.

Adipohaemocytes : These cells are usually rounded to ovoid in shape with a small ecentric nucleus in a large volume of cytoplasm. Many sharply outlined oil droplets are present in their cytoplasm. They often have a variety of other granular nonfat cytoplasmic inclusions which can obscure the nucleus. The nucleus is filled with large basophilic granules and forms a net work of chromatin. The cytoplasm is lightly eosinophilic.

From the study of differential haemocyte count (Fig. 2) it was found that in all nymphal stages of *R. nymphaeae*, prohaemocytes occur in the highest number.

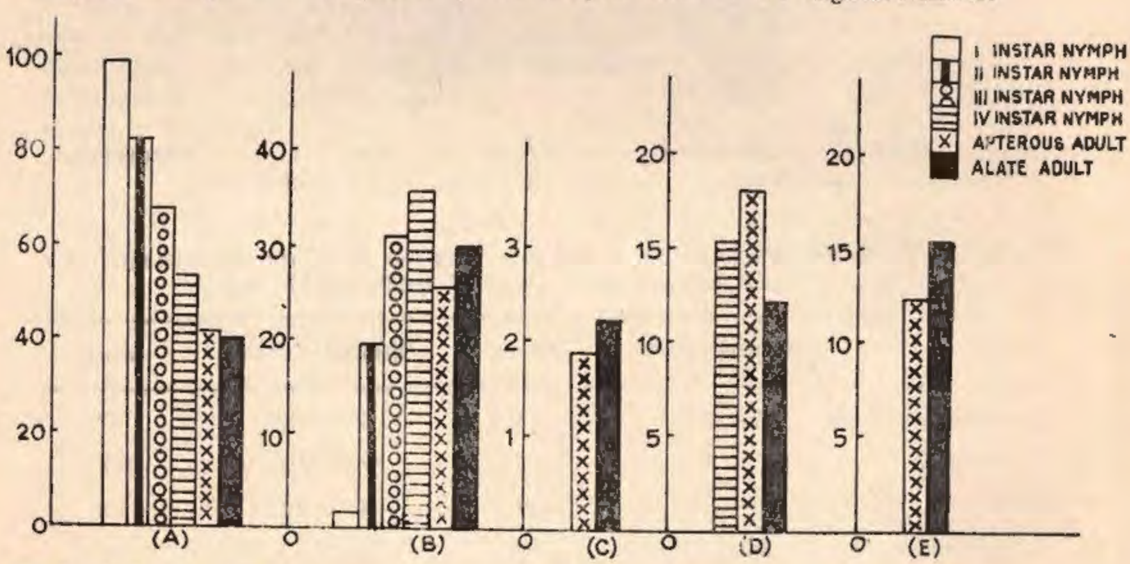

Fig. 2. A–E. Showing the percentage occurrence of different haemocytes, viz., (A) Prohaemocyte, (B) Plasmatocyte, (C) Podocyte, (D) Grannular haemocyte, and (E) Adipohaemocyte in different instars of *R. nymphaeae*.

In the first nymphal instar, prohaemocytes are found in large percentage, as high as 98% and plasmatocytes. 2% Granular haemocytes are only seen in the blood of fourth instar nymph and adult. Podocytes and adipohaemocytes exclusively belong to the adult forms.

Yeager (1945) described 32 types of haemocytes in insect haemolymph. Jones (1962) recognised nine main types viz., prohaemocytes, plasmatocytes, podocytes, granular haemocytes, oenocytoides, spherule cells, cystocytes, adipohaemocytes and vermiform cells. Patton (1963) states that the spindle cells and vermiform cells are not individual cell types. When viewed edge-wise, a plasmatocyte appears spindle shaped and when both the ends of the spindle are twisted it becomes a vermiform cell. The classification of Jones (1964) has mostly been followed by later workers like Gupta (1969, 1979) and Romoser (1973).

Boiteau and Perron (1976) noted five types of haemocytes in *M. euphorbiae* viz., prohaemocytes, plasmatocytes, granular haemocytes, spherule cells and oenocytes, while Behura and Dash (1979) found four types namely, prohaemocytes, plasmatocytes, podocytes and cystocytes. In *R. maidis* Behura and Bohidar (1983) described four types of haemocytes viz., prohaemocytes, plasmatocytes, granular haemocytes and podocytes in four species of aphids, namely, *P. nigronervosa*, *L. erysimi*, *M. sanborni* and *A. craccivora*. Haemolymph of all the above four species of aphids has a predominance of prohaemocytes and plasmatocytes. Excepting *P. nigronervosa*, all the remaining three have as pindle shaped plasmatocytes. Granular haemocytes are seen only in *P. nigronervosa* and *A. craccivora* while podocytes are noticed only in *M. sanborni* and *L. erysimi*. In the present investigation, the haemolymph of *R. nymphaeae* contain five types of haemocytes viz., prohaemocytes, plasmatocytes, granular haemocytes, podocytes and adipohaemocytes.

Boiteau and Perron (1976) found the five types of haemocytes in the III and IV instar nymphs and also adult of alate and apterous viviparous females as well as oviparous males and females. Behura and Dash (1979) reported that in *R. maidis* in the first instar nymph, the haemolymph contains only prohaemocytes and the haemolymph of remaining instars contain four types of haemocytes. In the present studies it was found that the first instar nymph contains a few plasmatocytes along with prohaemocytes and the remaining stages contain all the five types of haemocytes. In *M. euphorbiae*, Boiteau and Perron (1976) discovered granular haemocytes and plasmatocytes in highest numbers. However, the present studies reveal that prohaemocytes and plasmatocytes occur in the highest percentage which agrees with the results of Behura and Dash (1979).

Although the occurrence of haemocytes is concerned with the physiological condition of the insect (Jones 1967 ; Sharipo 1968 a, b) and the shape and size vary accordingly (Arnold 1972), the findings are interesting and a further study of the haemocytes of a larger number of aphid species will throw light of significant importance.

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STUDIES ON THE FECUNDITY, HATCHABILITY, MORTALITY AND LONGEVITY OF *MENOCHILUS SEXMACULATUS* FABR. (COLEOPTERA : COCCINELLIDAE)

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SUMMARY

Four aspects of *Menochilus sexmaculatus* Fabr. are described: (i) Facundity, (ii) Hatchability, (iii) Mortality and (iv) Longevity. *Aphis gossypii* complex was used as food during the study.

INTRODUCTION

Menochilus sexmaculatus Fabr. is a potential predator of aphids (Hukusima and Kouyama 1974). It has been recorded as a polyphagous species having a wide distribution in the Oriential region (Behura and Parida 1979 a, b ; Bose and Ray 1967 ; Chelliah 1971 ; Ghosh *et al.* 1981 ; Hukusima and Kamada 1972 ; Ray 1967 a, b ; Rao 1969).

Much study about the life history and feeding habits of this predator has been undertaken by some of the aforesaid workers, but there appears to exist scanty information in respect of fecundity, hatchability, mortality of developing stages and adult longevity of the species. This account embodies the result of investigations carried out on the above aspects of the species during the period, November 1980—March 1981.

MATERIAL AND METHODS

Adult males and females of *M. sexmaculatus* were brought to the laboratory collected on *Gossypium* sp. in the field infested with *Aphis gossypii* complex. One pair each of male and female was released in three sets of petridishes (9·2 cm diameter) provided with infested leaves of *Gossypium* sp.

Progeny of this pair of the predatory species were utilised for the purpose of the aforesaid study. The reared adult males and females, one pair in each set of petridishes, were allowed to mate under normal room conditions. Fecundity and hatchability of the eggs were noted every 24 hrs. In order to study the mortality of the developing stages of the predator, the hatched grubs were allowed to be reared on *A. gossypii* complex kept in glass jars (19 cm × 9 cm). After the attainment of adult stage, its longevity was observed.

RESULTS AND DISCUSSION

Fecundity-(Table 1) : Copulated females started ovipositing after 3–4 days of their emergence. They continued to lay eggs for 73–77 days. Interruptions in the oviposition period were noted which ranged from 1–8 days. Total fecundity varied between 1068–1391 eggs and average fecundity per day was found to vary between 14·63 to 18·06. Minimum and maximum number of eggs laid by a female varied from 4–5 and 49–58 respectively.

Hatchability-(Table 2) : Analysis of data presented in Tables 1 and 2 reveal that on an average 48·94% to 54·08% of the oviposited eggs successfully hatched out as first instar grubs. Thus, 45·92–51·06% eggs mortality was observed.

TABLE 1. Duration of oviposition and facundity in *M. sexmaculatus* Fabr.

	Oviposition period (in days)	Average fecundity/day	Total fecundity	Minimum no. of eggs laid per day	Maximum no. of eggs laid per day
1.	77	18·06	1391	5	49
2.	73	14·63	1068	4	58

TABLE 2. Records of hatching and mortality of eggs in *M. sexmaculatus* Fabr.

	Initial date of adult emergence	Initial date of oviposition	Final date of oviposition	Average hatching per day	Total hatching	% of hatching	% of egg mortality
1.	1·XII·1980	4·XII·1980	18·II·1981	8·68	669	48·94	51·06
2.	30·XI·1980	2·XII·1980	12·II·1981	7·90	577	54·08	45·92

Mortality-(Table 3) : A similar observation for developing grubs revealed that between 15 and 29·75% of the grubs did not attain the adult stage.

Longevity-(Table 4) : Adult females lived for 108–112 days while adult males lived for 80–84 days. Both males and females stopped feeding 2–3 days before death although the feeding rate decreased considerably in the last phase of life.

Analysis of the data reveals that about 50% of the fecundity potentiality of *M. sexmaculatus* is destroyed at the stage of hatching of the egg itself. Of the rest between 15 and 29·75% did not attain the adult stage.. The reared adults lived for 80–112 days.

TABLE 3. Percentage of mortality of developing stages of *M. sexmaculatus* Fabr.

	Number of first instar grub	Number of adult emerged	% of mortality
1.	40	29	29·75
2.	40	34	15·00
3.	40	31	22·50

TABLE 4. Adult longevity of males and females of *M. sexmaculatus* Fabr.

	Male longevity (in days)	Female longevity (in days)
1.	81	112
2.	84	110
3.	80	108

In terms of potentiality of the species as a predator of aphids, it appears that about 84–116 days in the life time of a single adult is utilised as active period of food consumption. Various works (*op. cit.*) have revealed that in terms of aphid number it comes to about 1500–2000.

No doubt, *M. sexmaculatus* is a potential predator of aphids, yet much of the potentiality of the predator is reduced due to appreciable motality of eggs and the developing stages because of reasons not better known. However, the survival proportion of the predator, if utilised appropriately, can exercise adequate biological control of aphids, more particularly of *A. gossypii* complex. For this further knowledge have to be gained about the ecosystem of aphid-predator-host plant.

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RELATIVE TOLERANCE TO APHID, *RHOPALOSIPHUM MAIDIS* FITCH IN BARLEY GERMPLASM

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SUMMARY

Field evaluation of 197 barley lines was done against corn aphid, *Rhopalosiphum maidis*. These lines were categorised as 19 tolerant, 75 moderately susceptible, 77 susceptible and 26 lines as highly susceptible on the basis of their reaction towards the pest. Lines K-50, -67, -80, -85, -92, IC-35773, BP/RC-41, NP/UK-235, Icarda-19, -139, -167, 206 and Leningrad-93 were significantly less infested by the aphid as compared to other test entries.

INTRODUCTION

Corn aphid, *Rhopalosiphum maidis* Fitch (Aphididae : Homoptera) is an important pest of many graminacious crops. This aphid has been known to cause economic losses in maize, sorghum, barley, oats, wheat and jawar. Barley which is grown for fodder and grain, suffers losses upto 25% by this aphid (Bhatia *et al.* 1971). The aphid is greenish blue in colour and generally feeds within the plant whorl. Evolving aphid resistant lines seems to be a better proposition for economic control of this pest. Attempts have been made by various workers in identifying resistant lines of barley (Murty *et al.* 1968 ; Bhatnagar *et al.* 1972 ; Sagar Singh *et al.* 1983).

The present studies were undertaken to screen the base material consisting of a large number of breeding lines and varieties and further categorizing them into various groups based on their tolerance to aphid attack. This will form the foundation for persuing further studies in order to determine the exact nature of resistance and help the plant breeders in evolving high yielding aphid resistant lines.

MATERIALS AND METHODS

One hundred and ninety seven lines of barley were grown in 2 m rows 30 cm apart in two replication at Indian Grassland and Fodder Research Institute, Jhansi on 6th December, 1985. These were screened for reaction to corn aphid attack under natural conditions of infestations at 40 days. After 50 days first cut of the crop was taken for fodder and the lines which showed higher regeneration quality were subjected to another observation for aphid recorded at 70 days. The number of aphids per plant including nymphs and adults were physically counted on five randomly selected plants. Individual line(s) were classified into four grades on the basis of intensity of aphid infestation as under : Tolerant, 1–20 aphids/plant ; Moderately susceptible, 21–40 aphids/plant ; susceptible, 41–70 aphids/plant and highly susceptible, 71 and above aphids/plant.

RESULTS AND DISCUSSION

No barley line displayed immunity to aphid attack. The analysis of variance indicated that sufficient variation for number of aphids exists among different lines. Out of 197 lines screened 19 were found tolerant, 75 moderately susceptible, 77 susceptible and 26 highly susceptible. Each entry with its grouping is given in Table 1. The lines which have better regeneration capacity or suitable for second cut were Barley–15 ; Ratna, BP/UK–235,–241 ; Karan, K–300 ; Leningrad–67,–93; Icarda–206 and 209. These lines had lower aphid infestation at 70 days observation. This indicates that cutting crop at 50 days help in lowering the aphid incidences through removal of aphids along with cut forage.

TABLE 1. Number of aphids per plant in different Barley lines.

No.	Line	No. of aphids/plant (at 40 days)	(at 70 days)
	Tolerant		
1.	BP/RC–41	3·00	4·00
2.	K–67	4·20	—
3.	Icarda–167	4·60	—
4.	Icarda–206	5·10	4·80
5.	K–50	5·30	—
6.	K–92	6·00	—
7.	K–85	6·20	—
8.	Leningrad–93	6·00	—
9.	IC–36973	7·50	6·80
10.	K–80	7·80	—
11.	Icarda–19	8·80	—
12.	Icarda–139	9·70	—
13.	BP/UK–235	9·80	7·60
14.	Icarda–153	10·10	—
15.	K–709	10·50	—
16.	K–713	10·50	—
17.	Leningrad–29	11·60	—
18.	Icarda–131	11·80	—
19.	BP/RC–63	14·00	—
	Moderately Susceptible		
20.	Leningrad–34	22·20	—
21.	Icarda–9	22·70	—
22.	Leningrad–54	23·20	—

TABLE 1. Continued

No.	Line	No. of aphids/plant (at 40 days)	(at 70 days)
23.	BP/UK-219	23·30	—
24.	BP/RC-154	23·60	—
25.	BP/RB-98	24·10	—
26.	K-143	24·60	—
27.	Leningrad-56	24·60	—
28.	BP/UK-172	25·30	—
29.	BP/UK-156	25·50	—
30.	Icarda-210	26·20	—
31.	BP/RC-7	26·40	—
32.	Leningrad-67	27·00	18·60
33.	Icarda-67	27·20	—
34.	IC-36777	27·60	—
35.	Icarda-109	27·60	—
36.	BP-442	27·80	14·40
37.	Icarda-62	27·90	—
38.	K-734	28·30	—
39.	BP-602	28·50	—
40.	Icarda-150	30·50	—
41.	BG-105	28·60	—
42.	IC-36899	28·70	—
43.	BP/RC-171	28·80	—
44.	Icarda-13	28·80	—
45.	Icarda-114	28·80	—
46.	K-34	29·00	—
47.	Icarda-120	29·10	—
48.	K-130	29·20	—
49.	BP/RC-160	29·50	—
50.	BP/RC-163	29·70	—
51.	IC-36902	29·80	—
52.	Icarda-156	29·80	—
53.	Icarda-158	29·80	—
54.	IC-36945	30·00	—
55.	Icarda-94	30·00	—
56.	Leningrad-25	30·00	—
57.	IC-36947	30·50	—
58.	BP/RC-10	30·50	—
59.	IC-36947	30·50	—
60.	BP/RC-102	30·50	—
61.	BP/RC-23	30·50	—
62.	BP/RC-104	30·90	16·80
63.	Icarda-124	31·20	—
64.	BP/UK-158	31·30	—
65.	Ratna	31·40	15·80
66.	BG-25	31·40	—
67.	BP/RC-71	31·50	—
68.	BP/UK-217	31·60	—
69.	BP/RC-38	32·00	—

TABLE 1. Continued

No.	Line	No. of aphids/plant (at 40 days)	(at 70 days)
70.	BP/RB-18	32·00	—
71.	K-98	32·10	—
72.	BP/UR-241	32·40	20·00
73.	BP-126	32·80	—
74.	K-132	32·90	—
75.	Icarda-243	33·00	—
76.	K-88	33·00	—
77.	Icarda-239	33·20	—
78.	BP/RC-96	33·30	—
79.	BP/UK-168	33·30	—
80.	RD-87	33·30	—
81.	BG-90	33·50	20·20
82.	IC-36953	33·60	—
83.	BP-RC-69	33·90	—
84.	BP-483	34·00	—
85.	K-221	34·20	—
86.	IC-36769	34·40	—
87.	K-677	34·40	—
88.	Karna	34·50	20·60
89.	Icarda-240	34·60	—
90.	IC-36946	37·10	—
91.	Icarda-213	37·10	—
92.	Icarda-25	38·20	—
93.	K-110	39·80	—
94.	Icarda-209	40·10	21·20
	Susceptible		
95.	Icarda-122	41·60	—
96.	BP/UK-254	52·00	—
97.	K-714	43·00	—
98.	Icarda-104	43·40	—
99.	BP/RC-161	43·80	35·20
100.	BP/RC-129	45·60	—
101.	K-42	46·20	—
102.	BP/RC-42	46·30	—
103.	K-683	48·60	—
104.	BP/RC-18	48·80	—
105.	IC-36948	60·00	—
106.	K-638	50·00	—
107.	Icarda-180	50·30	—
108.	K-78	50·40	—
109.	BP/RC-93	50·40	—
110.	BP/RC-78	50·50	—
111.	RD-51	50·50	—
112.	BP/RC-54	50·70	—
113.	K-55	51·60	—
114.	IC-36955	51·60	—

TABLE 1. Continued

No.	Line	No. of aphids/plant (at 40 days)	(at 70 days)
115.	Icarda–181	51·30	—
116.	Icarda–21	51·50	—
117.	BP/UK–250	52·00	—
118.	BP/RC–16	52·30	—
119.	BP/RC–36	52·35	—
120.	BP/RC–17	52·40	—
121.	Leningrad–81	62·50	—
122.	Icarda–262	52·80	—
123.	Icarda–183	53·30	—
124.	BP/RC–31	53·40	40·20
125.	BP/UK–231	53·40	—
126.	K–51	53·60	—
127.	K–300	53·60	30·80
128.	Barley–15	54·30	25·60
129.	Barley–20	54·30	—
130.	BP/RC–83	54·50	—
131.	RD–36	54·90	—
132.	Icarda–54	55·00	—
133.	Icarda–58	55·30	—
134.	Leningrad–78	55·30	—
135.	IC–36772	55·40	—
136.	Barley–17	55·50	—
137.	K–319	55·60	—
138.	BP/RC–103	55·70	—
139.	K–646	57·00	—
140.	K–304	56·30	—
141.	Barley–348	56·30	—
142.	Icarda–73	56·50	—
143.	Icarda–134	57·00	—
144.	IC–36942	57·50	—
145.	IC–36904	57·75	—
146.	Icarda–188	57·90	—
147.	K–59	58·00	—
148.	K–24	58·20	—
149.	BP/RC–110	58·40	—
150.	Leningrad–42	58·60	—
151.	RD–250	58·60	—
152.	IC–36950	58·90	—
153.	K–713	59·00	—
154.	BP/RC–48	59·10	—
155.	BP/RC–21	59·30	—
156.	Icarda–155	59·40	—
157.	K–89	59·70	—
158.	BP/RC–112	59·90	—
159.	BP/RB–34	60·20	—
160.	K–287	60·30	—
161.	K–53	60·40	—
162.	Leningrad–69	61·10	—

TABLE 1. Continued

No.	Line	No. of aphids/plant (at 40 days)	(at 70 days)
163.	BP/RC-114	61·70	—
164.	Icarda-23	61·70	—
165.	BP/RC-186	62·10	—
166.	BP/RC-53	62·20	—
167.	Leningrad-4	62·60	—
168.	Icarda-105	62·90	—
169.	BP/UK-216	63·70	—
170.	BP/UK-195	64·70	—
171.	BP/UK-199	67·50	—
	Highly susceptible		
172.	Leningrad-65	71·30	—
173.	BP/RC-153	72·40	—
174.	BP/UK-132	73·50	—
175.	Icarda-129	73·80	—
176.	BP/UK-223	74·90	—
177.	Icarda-159	75·00	—
178.	BP/RC-84	75·40	—
179.	IC-36952	75·50	—
180.	BP/RC-15	75·50	—
181.	Leningrad-37	75·50	—
182.	BP-551	76·00	38·60
183.	BP/RC-159	76·30	—
184.	BP/RC-108	76·30	—
185.	BP/RC-39	76·60	—
186.	Icarda-68	77·80	—
187.	Icarda-200	77·80	—
188.	K-58	78·60	—
189.	Leningrad-76	79·70	—
190.	BP-20	80·50	—
191.	BP-303	80·70	—
192.	BP/UK-204	81·40	—
193.	BP/RC-79	82·30	—
194.	BP/RC-116	82·80	—
195.	BP/RC-56	85·50	—
196.	IC-36949	85·80	—
197.	K-68	89·20	—
– F Test		Sig.	Sig.
– S. Em		± 5·877	± 2·982

The lines, Leningrad-67, BP/UK-241, BP-442 and K-54 gave higher green fodder yield as compared to other lines. These lines are either moderately tolerant or susceptible to aphid attack. It can be concluded that green fodder yield of these lines can be enhanced further by avoiding losses due to aphid.

Gulati *et al.* (1978) reported a wide range of variation in the aphid population built up on different susceptible plants in the F_2 and BC_1 and three way segregating population suggested the operation of modifier genes governing the intensity of infestation. Other workers like Bhatnagar *et al.* (1972) ; Sagar Singh and Bhatia (1' 83) ; Sajjan *et al.* (1985) also reported high degree of variation among barley germplasm for resistance to this aphid. Nevertheless for having a long lasting resistance to barley aphid, it is necessary that new genes for resistance are identified for incorporation into the varieties.

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WEATHER FACTORS IN RELATION TO *MYZUS PERSICAE* (SULZER) BUILDUP ON POTATO CROP

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SUMMARY

Among abiotic factors, temperature is the most influencing factor in controlling the growth of *Myzus persicae*. The landing and settling of *M. persicae* on potato crop takes place at the weekly mean maximum and minimum temperatures 20·4°C—24·9°C and 3·5°C—7·7°C in December at Modipuram (District Meerut, U.P.). The weekly mean maximum and minimum temperatures of 25·3°C—25·6°C and 6·3°C—9·5°C are most suitable for the rapid multiplication of the aphid species during the first to third week of February. Thereafter, temperature increases to 26·1°C in the fourth week ot February which checks its further multiplication. In March, weekly mean maximum and minimum temperatures range from 28·0°C to 33·2°C and from 10·5°C to 14·1°C respectively and there is also scarcity of suitable host plants. These conditions affect aphid populations adversely resulting in their disappearance. Humidity and rainfall do not seem to play significant role in an aphid build up. Increase in wind velocity during March varies from 4·37 km to 5·78 km per hour and aids in carrying away the alate morphs produced, to long distances.

INTRODUCTION

Myzus persicae (Sulzer) is one of the most destructive insects attacking the potato crop throughout the world. It also transmits over 100 virus diseases of plants on about thirty different families including potato (Kennedy *et al.* 1962). Amongst potato viruses, leafroll and virus 'Y' are very serious diseases. In India, due to viruses potato, yield is reduced by 25–80% (Nagaich 1974). By the use of healthy seed tubers about 50% of the annual loss in yield can be prevented (Pushkarnath 1959).

The use of chemical methods to prevent spread of viruses by controlling the aphid vectors has either been unsuccessful or only partially successful. The new seed potato strategy demands fuller data on weather-aphid buildup relationship to understand the behaviour of *M. persicae* on the crop. Weather factors include temperature, humidity, rainfall, wind velocity and light intensity, which have a direct influence on insect distribution and abundance. The paper deals with these factors in relation to *M. persicae* buildup.

MATERIAL AND METHODS

Aphid populations were recorded at weekly interval by 100 leaves index method (Simpson 1940). The method consists of counting aphids on equal number of leaves selected at random from the bottom, middle and top of 33 plants and one from the bottom of the 34th plant. The observations were recorded on unsprayed, Kufri Badshah, Kufri Lalima, Kufri Bahar and Kufri Chandramukhi varieties at two locations of the farm of Central Potato Research Station, Modipuram District Meerut (U.P.). The data were recorded from December 1986 to middle of February 1987 in autumn and again in spring planted crop upto the end of March 1987. Meteorological data in the form of maximum and minimum temperatures, relative humidity, rainfall and wind velocity were also recorded.

RESULTS AND DISCUSSION

It is apparant from the data (Table 1) that the initial setting up of *M. persicae* on potato crop at the farm takes place during December. The mean population of *M. persicae* recorded on unsprayed potato varieties Kufri Badshah, Kufri Lalima, Kufri Bahar and Kufri Chandramukhi was 0·50 and 0·62 aphids per 100 leaves in 3rd and 4th week of the December respectively (Table 1), indicating its low buildup during this period. Meteorological data showed weekly mean maximum temperature were 20·4°C to 24·9°C and minimum 3·5°C to 7·7°C during this period. The mean monthly maximum and minimum temperatures were 22·1°C and 5·8°C (Table 2). As there was a good canopy and greenery of this crop at this time, the aphids were attracted to these nutritionally suitable plants or parts of plants. Similiar results were obtained in other places (Kennedy *et al.* 1961). Thus the stage of the host and weather conditions were both suitable for landing and settling of *M. persicae* during this month on potato crop.

The weekly mean maximum and minimum temperature recorded during 1st, 2nd, 3rd and 4th week of January 1987 ranged from 18·1°C to 23·5°C and 5·3°C to 7·4°C respectively, the mean monthly maximum and minimum being 21·7°C and 5·9°C which were almost very close to the mean monthly maximum and minimum temperatures (22·1 and 5·8°C) of December 1986 (Table 2). Because of this the multiplication rate of *M. porsicae* remained slow and ranged from 1·0 to 126·0 aphids per 100 leaves during this period on these varieties included in the experiment. The monthly mean aphid population was found to be 92·43 aphids per 100 leaves (Table 1).

Thereafter, rapid buildup of the aphid was recorded. The population of *M. persicae* reached its peak in the 2nd or 3rd weeks of February, as the temperature abruptly increased to 25·6°C in the first week of February. The weekly mean maximum and minimum temperature recorded from first week of February to third week of February ranged from 25·3°C to 25·6°C and 6.3°C to 9.5°C respectively.

TABLE 1. Population of *M. persicae* per 100 leaves on four potato varieties at Modipuram during 1986–87.

Months	Week	Site	Variety: Kufri Badshah	Kufri Lalima	Kufri Bahar	Kufri Chandramukhi	Total	Mean Population
December	I	I	0·0	0·0	0·0	0·0	0·0	0·0
		II	0·0	0·0	0·0	0·0	0·0	
	II	I	0·0	0·0	0·0	0·0	0·0	0·0
		II	0·0	0·0	0·0	0·0	0·0	
	III	I	0·0	0·0	2·0	1·0	3·0	0·50
		II	0·0	1·0	0·0	0·0	1·0	
	IV	I	0·0	0·0	2·0	0·0	2·0	0·62
		II	0·0	0·0	2·0	1·0	3·0	
Mean month								0·28
January	I	I	12·0	12·0	26·0	28·0	78·0	19·12
		II	1·0	41·0	13·0	21·0	75·0	
	II	I	40·0	12·0	29·0	27·0	108·0	19·00
		II	2·0	12·0	79·0	9·0	42·0	
	III	I	68·0	126·0	33·0	35·0	262·0	65·50
	IV	I	87·0	51·0	97·0	90·0	325·0	81·25
Mean month								92·43
February	I	I	608·0	327·0	387·0	1576·0	3948·0	987·00
	II	I	1822·0	418·0	414·0	1772·0	4426·0	1108·50
	III	I	1121·0	249·0	1611·0	1014·0	3995·0	998·75
	IV	I	145·0	151·0	519·0	1003·0	1818·0	454·50
Mean month								886·68
March	I	I	97·0	140·4	42·0	161·0	450·0	112·60
	II	I	15·0	19·0	16·0	26·0	76·0	19·00
	III	I	0·0	4·0	4·0	3·0	11·0	2·75
	IV	I	0·0	0·0	0·0	0·0	0·0	0·00
Mean month								33·58

Site I = Location I at Modipuram
Site II = Location II at Modipuram.

TABLE 2. Mean monthly weather data during crop season (1986-87) at Modipuram.

Months	Week	Temperature (°C) Max	Temperature (°C) Min	Relative humidity (%) Morning	Relative humidity (%) Evening	Rain fall (mm)	Wind velocity (km/hr) Morning	Wind velocity (km/hr) Evening
December	I	24·9	7·6	86·0	42·0	0·0	0·61	3·01
	II	21·1	7·7	91·0	55·0	2·3	2·65	5·72
	III	20·4	4·6	88·0	47·0	0·0	0·33	2·51
	IV	22·3	3·5	88·0	38·0	0·0	0·49	2·83
Mean month		22·1	5·8	88·2	45·5	—	1·02	3·51
January	I	23·0	5·5	86·0	43·0	0·0	1·30	3·30
	II	22·4	7·4	93·0	52·0	0·0	1·41	3·00
	III	18·1	5·5	96·8	66·8	2·4	3·01	3·30
	IV	23·5	5·3	92·0	46·0	0·0	1·04	3·25
Mean month		21·7	5·9	91·9	51·9	—	1·69	3·21
February	I	25·6	6·3	92·0	44·0	0·0	0·53	2·88
	II	25·3	8·5	91·0	43·0	0·5	1·66	4·72
	III	25·5	9·5	88·0	49·0	0·0	2·70	4·17
	IV	26·1	9·8	89·1	44·5	1·0	3·22	3·74
Mean month		25·6	8·5	90·0	45·1	—	2·02	3·87
March	I	28·2	10·7	87·0	42·0	0·0	1·29	4·37
	II	28·0	10·5	88·0	46·0	0·0	2·91	4·65
	III	31·2	13·3	83·0	38·0	0·0	3·15	5·43
	IV	33·2	14·1	89·0	44·0	12·0	3·29	5·78
Mean month		30·1	12·1	86·7	42·5	—	2·66	5·05

On variety Kufri Badshah the aphid population recorded was as high as 1822·0 aphids per 100 leaves followed by Kufri Chandramukhi (1772·0 aphids per 100 leaves) in the 2nd week of February. The mean population ranged from 987·0 to 1106·5 aphids per 100 leaves from 1st week of February to 3rd week of February. However, on all the four varieties *i.e.* Kufri Badshah, Kufri Bahar, Kufri Lalima and Kufri Chandramukhi the population varied from 327·0 to 1822·0 aphids per 100 leaves (Table 1).

During the fourth week of February, the population of the aphid species started declining with rise in temperature and stood at 145·0 to 1003·0 aphids per 100 leaves on these varieties (Table 1). The weekly mean maximum and minimum temperatures recorded were 26·1 and 9·8°C respectively. Pushkarnath and Nirula (1970) state that temperature above 26°C ceases the reproductive activity of *M. persicae*. It was also observed that due to maturity of the crop at this stage the potato foliage physically as well as nutritionally became unsuitable for the multiplication of the aphid. Thus with scracity of suitable host plants and rise in temperature during this period, further development of *M. persicae* was checked.

In March 1987, further rise in temperature was observed. The weekly mean maximum and minimum temperatures recorded were 28·0°C to 28·2°C, 10·5°C to 10·7°C respectively (Table 2) upto the middle of March and thus were responsible for drastic decline of aphid number. The aphid population now ranged from 15·0 to 161·0 aphids per hundred leaves (Table 1). Barlow (1962) and Van der Plank (1944) also found that temperature above 28·0°C prevents development of aphid.

The temperature goes on rising further and the weekly mean maximum and minimum temperature recorded were 31·2°C to 33·2°C and 13·3°C to 14·1°C respectively upto the end of March (Table 2). This strongly effected aphid population and eventually aphids disappeared from the potato foliage. Dickson and Laird (1967) state that *M. persicae* populations almost disappear when maximum temperature reaches 32·0°C and are replaced annually by migrants cooler, moist regions *e.g.* hills and mountains.

Humidity and rainfall do not seem to play much role in aphid buildup. The wind velocity increased in the month of March from 4·37 to 5·78 km/h (Table 2) helped in carrying away the alate aphids to long distances. This is also the time when large number of alate morph formation takes place (Verma 1986).

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STRATIGRAPHIC DISTRIBUTION AND HOST ASSOCIATION OF APHIDINAE APHIDS (HOMOPTERA : APHIDIDAE) OF GARHWAL RANGE OF WESTERN HIMALAYA

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SUMMARY

Aphidinae is the largest subfamily of the family Aphididae (Homoptera). Uptill now altogether 141 species of, aphids are known from Garhwal range of Western Himalaya. Out of these 86 species belong to this subfamily which comprises more than 60% of the total species so far explored from this region. The species have been collected from different altitudes and hosts. The altitudinal distribution in relation with vegetation and the host association of aphidinae species of Garhwal region of Western Himalaya, India are dealt in this paper.

INTRODUCTION

Aphidinae the largest subfamily of the family Aphididae (Homoptera) is capable of adapting a wide range of ecological parameters viz., temperature, rainfall, altitude and humidity. This subfamily embodies more than half of the number of aphid species when compared to the total aphid fauna so far been explored from the world (Eastop 1977). Since Buckton (1893) at present altogether 141 species of aphids distributed over 73 genera are known from Garhwal range of Western Himalaya (Bhattacharya *et al.* 1983 ; Chakrabarti *et al.* 1983 ; Maity *et al.* 1984 ; Chakrabarti and Maity 1984 ; Chakrabarti and Bhattacharya 1985 ; Chakrabarti and Raha 1985 ; Medda and Chakrabarti 1986 ; Charkrabarti *et al.* 1987). Out of 141 species, 86 species distributed over 43 genera belong to the subfamily Aphidinae which comprises about 60% of the total species so far been explored from this region.

Ghosh and Raychaudhri (1979) provided the altitudinal distribution of Aphidinae species of Darjeeling district (W. B.) and Sikkim. Later, Maity *et al.* (1984) provided the stratigraphic distribution of the aphids from Garhwal range. But distribution aphids in correlation with vegetational belts were not considered in the above works.

MATERIAL AND METHOD

Aphid species collected by Biosystematics Research Unit, Department of Zoology from different altitudes and host plants of Garhwal range in different seasons were studied. The stratigraphic distribution in relation with vegetational pattern and the host association of these aphids in the area are dealt in this paper.

RESULTS AND DISCUSSION

Stratigraphic Distribution :

The abundance of aphid species under the subfamily Aphidinae in localities situated at different altitudinal strata in correlation with vegetational belts of Garhwal Range was studied. Following Dudgeon and Kenoyer (1925) ; Kashyap (1925) ; Osmaston (1922) ; Gupta (1957, 1962) the vegetational area in relation to altitude can be divided with 4 regions viz., Tropical region extending from c 300 m—c 900 m, Subtropical region extending from c 900 m—c 2000 m, Temperate region from c 2000 m—c 3600 m and Alpine region from c 3600 m—c 5500 m. Usually different altitudinal zones have different vegetation type, although overlapping flora may frequently occur. The tropical region occupied mainly by plants like *Chrysanthemum* spp., *Agaretum* spp., *Browallia* spp., *Artemisia* spp., *Cestrum* app., *Dolichos* spp., *Toddalia* spp., *Lagerstromia* spp. etc. and different species of grasses are the important host plants of aphidinae species. There exists 27 species under 15 genera of the aphidinae aphids in this region.

The subtropical region characterised by having different species of *Alnus*, *Prunus*, *Artemisia*, *Berberis*, *Cestrum*, *Geranium*, *Lyonia*, *Rubus*, *Rosa*, etc. as the main host plants of aphidinae species embodies 55 species distributed over 31 genera.

The temperate region having *Prunus*, *Lonicera*, *Rhododendron*, *Salix*, *Impatiens*, *Hydrangea*, *Viburnum*, as the principal host plants for aphidinae species represented by 72 species over 37 genera in this region.

The Alpine region having *Rhododendron*, *Viburnum*, *Betula*, *Sorberia* etc. as the predominant plant genera harbour 20 species distributed over 14 genera of the aphidinae aphids.

The vertical distribution of the total genera and species of this subfamily in relation with vegetational belts have been represented in the Fig. 1.

It can be analysed that the temperate vegetational belt appears to be most preferred niche for aphidinae aphids. This zone is the richest as regards the number and diversity of the aphidinae group.

It also indicates that the temperate zone comprises more than 83% of the total Aphidinae species and 51% of the total aphid species so far explored from Garhwal Range. While Alpine zone consists the lowest percentage (23·25%) of the Aphidinae species and also lowest (14·18%) number when compared these Aphidinae species with the total aphids explored from Garhwal Range. The Tropical and subtropical regions comprise 31·39% and 63·95% of the aphidinae

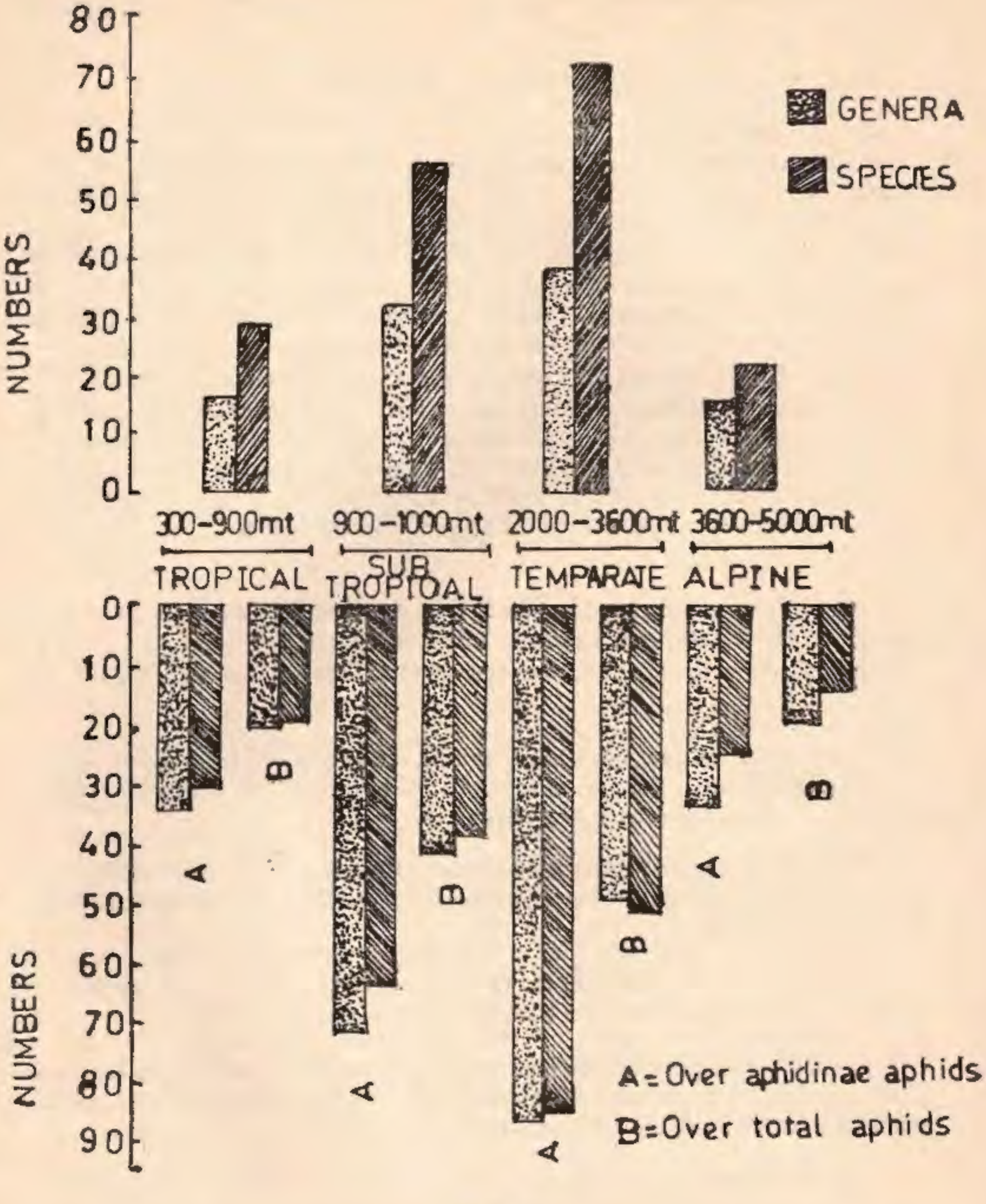

Fig. 1.

species and 19·14% and 39% when compared to the total species explored from Garhwal Range, respectively.

The composition of aphidinae species in each stratum is some what distinctive, although some species like *Toxoptera auranti*, *Macrosiphoniella pseudoartimisae*, *Avicennina indica*, *Hayhurstia atriplicis* may found in contiguous belts as because of the overlapping floral composition between the contiguous strata. But when considering the species typical for a particular altitudinal zone, it appears that Alpine region is very distinctive, because it harbours mostly the typical plant species for this particular region.

It has also been observed that few species like *Aphis gossypii*, *Aphis spiraecola*, *Brachycaudus helichrysi* and *Myzus persicae* could be found in each of the strata in the present area of study irrespective of any altitude and floral composition as because all those species are highly polyphagous species and infest large number of hosts belonging to unrelated families and possess their habit of cosmopolitan distribution.

Host Association :

The 86 species of aphidinae aphids have been found to infest the plants belonging to 48 plant families distributed over 91 plant genera and 119 plant species, It has been observed that most of the aphidinae species live on higher dicotyledonous plants, while few on monocotyledonous plants. It has also been found that among the plant families Compositae harbour the maximum number aphidinae species (20) followed by Rosaceae (14) and Graminae (13). Hence they act as the predominant plant families for the aphidinae hosts.

Members of the subfamily aphidinae show host alternation (Eastop 1977). In the present area of study most well known alternating species are *Myzus cerasi* which alternate between cherry (Primary host) and *Artemisia*, *Cardanine* (Secondary hosts) ; *Capitophorus hippophae* alternate between *Hippophae* (Primary host) and *Polygonum* (Secondary host) ; *Brachycaudus helichrysi* alternate between *Prunus* (Primary host) and *Anaphalis*, *Agaretum*, *Erigeron* (Secondary hosts). Many species like *Aphis gossypii*, *Aphis citricola*, *Myzus persicae* are highly polyphagous belonging to this subfamily show host alternation, where primary hosts are some what definite but with a wide range of secondary hosts. Species like *Amphicercidus lonicerae*, *Avicennina indica*, *Ceruraphis eastopi* etc. are seem to be host alternating species as they have been obtained from their primary hosts and in these cases the secondary hosts yet to be determined. In case of *Myzus cornuta*, *Eumyzus prunicolus* and many others the host alternating habit is till to be obscured from the present area. So the host alternating and holocyclic life pattern of the aphidinae species in this area is very common as evidence by the presence of fundatrix in many cases.

Table 1 indicates the degree of host specificity of aphidinae species. It could be found that a substantial percentage (66·79%) of aphidinae aphids is restricted to a single plant family. About 48·83% of species are restricted to one plant species, while altogether 33·71% of species occur in two or more groups of plants.

TABLE 1. Degree of host specificity in aphidinae aphids.

Host specificity	No. of aphidinae species	% over Total aphidinae species
Aphids restricted to one plant species	42	48·83
Aphids restricted to one plant Genus	48	55·81
Aphids restricted to one plant Family	57	66·79
Aphids restricted to 2-4 plant Families	24	27·90
Aphids restricted to 5 Or more plant Families	05	05·81

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CHROMOSOME NUMBERS OF INDIAN APHIDS : THEIR POSSIBLE EVOLUTION AND TAXONOMIC SIGNIFICANCE

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SUMMARY

Diploid chromosome numbers for twenty two Indian aphid species are listed. Majority of them are known to have even number of chromosomes while the two species viz., *Aphis achyranthi* and *Capitophorus hippophaes mitegoni* have odd numbers. In the present paper the possible evolution and the modal numbers for various genera have been discussed in order to establish the possible correlation with their taxonomic significance.

INTRODUCTION

So far chromosome numbers for more than 685 species of Aphidoidea have been published world over (Kuznetsova and Shaposhnikov 1973 ; Gut 1976 ; Blackman 1980, 1986 ; Kurl 1986 a). The contribution of Indian Cytogeneticists for the study of aphids stands at about 104 Indian species (Chauhan 1987). Unfortunately the workers in this country could pay attention only for just reporting the chromosome numbers of aphids rather than carrying out thorough investigations with them. Aphids as a whole are the good material for genetical studies as they have many advantages over other insect groups (Sapunov and Kuzentsova 1987). So far, the assessments of the evolutionary implication of aphid chromosome numbers have been based on the information about only few species (Shinji 1931, Steffan 1968).

In the present paper, in the light of chromosome numbers of certain species of aphids, an attempt has been made to know the phylogenetic relationship within the family Aphididae, and to use this information in practical taxonomy.

MATERIALS AND METHODS

Chromosome air-dry preparations were made using young embryos dissected out from the freshly collected aphids from different localities of Himachal Pradesh, India (Table I). The dissection was done in hypotonic sodium citrate solution (0·5%) and the early embryos were then fixed in 3 : 1 methanol, glacial acetic acid for 10–15 minutes and thereafter two changes of this fixative were made. When the embryos turned white, they were transfered onto the slide and crushed in a small drop of 60% acetic acid and were subject to airdrying. Later on these slides were stained in 10% Giemsa stain and finally mounted in D. P. X.

In order to ascertain the chromosome numbers in each species atleast 25 mitotic complements were selected and counted. In each species the chromosomal measurements were taken from well spread complements and their mean values were used for the preparation of Idiograms (Figs. 19–40). Chromosomes marked with asterisks in idiograms are unpaired and they may be treated as sex chromosomes.

TABLE 1. Chromosome numbers for 22 species of Aphididae and their place of collection.

Aphid Species	Chromosome Number (2n) (Somatic cells)	Place of Collection	Idiogram No.
Subfamily–Aphidinae			
Amphorophora ampullata bengalensis H.R.L. and Basu	12	Manali	19
Aphis achyranthi Theobald	7	Solan	20
Aphis citricola van der Goot	8	Kangra	21
Aphis kurosawai Takahashi	8	Solan	22
Aphis paraverbasci Chakrabarti	8	Solan	23
Aphis ruborum longisetosus A. N. Basu	6	Solan	24
Brachycaudus rumexicolens (Patch)	12	Barog	25
Capitophorus hippophaes mitegoni Eastop	9	Manali	26
Hyperomyzus carduellinus (Theobald)	12	Naldehra	27
Impatientinum asiaticum dalhousiensis Verma	16	McCload Gang	28
Indomasonaphis inulae (Ghosh and Raychaudhuri)	32	Barog	30
Lisomaphis atra H. R. L.	18	Barog	29
Macrosiphum miscanthi Takahashi	18	Solan	31
Metopolophium rubi (Narz.)	12	Barog	32
Myzakkia verbasci Chowdhuri, Basu, Chakrabarti and Raychaudhuri	12	Manali	33
Myzus cerasi umefoliae (Shinji)	12	Solan	34
Myzus dycei Carver	12	Solan	35
Myzus obtusirostris David, Narayanan and Rajasingh	12	Barog	36
Uroleucon pseudotenaceti Verma	12	Kangra	37
Uroleucon simlaensis Chakrabarti, Ghosh and Raychaudhuri	12	Kandaghat	38
Uroleucon sonchi (L.)	12	Barog	39
Subfamily–Lachninae			
Cinara maculipes H. R. L.	12	Chail	40

RESULTS AND DISCUSSION

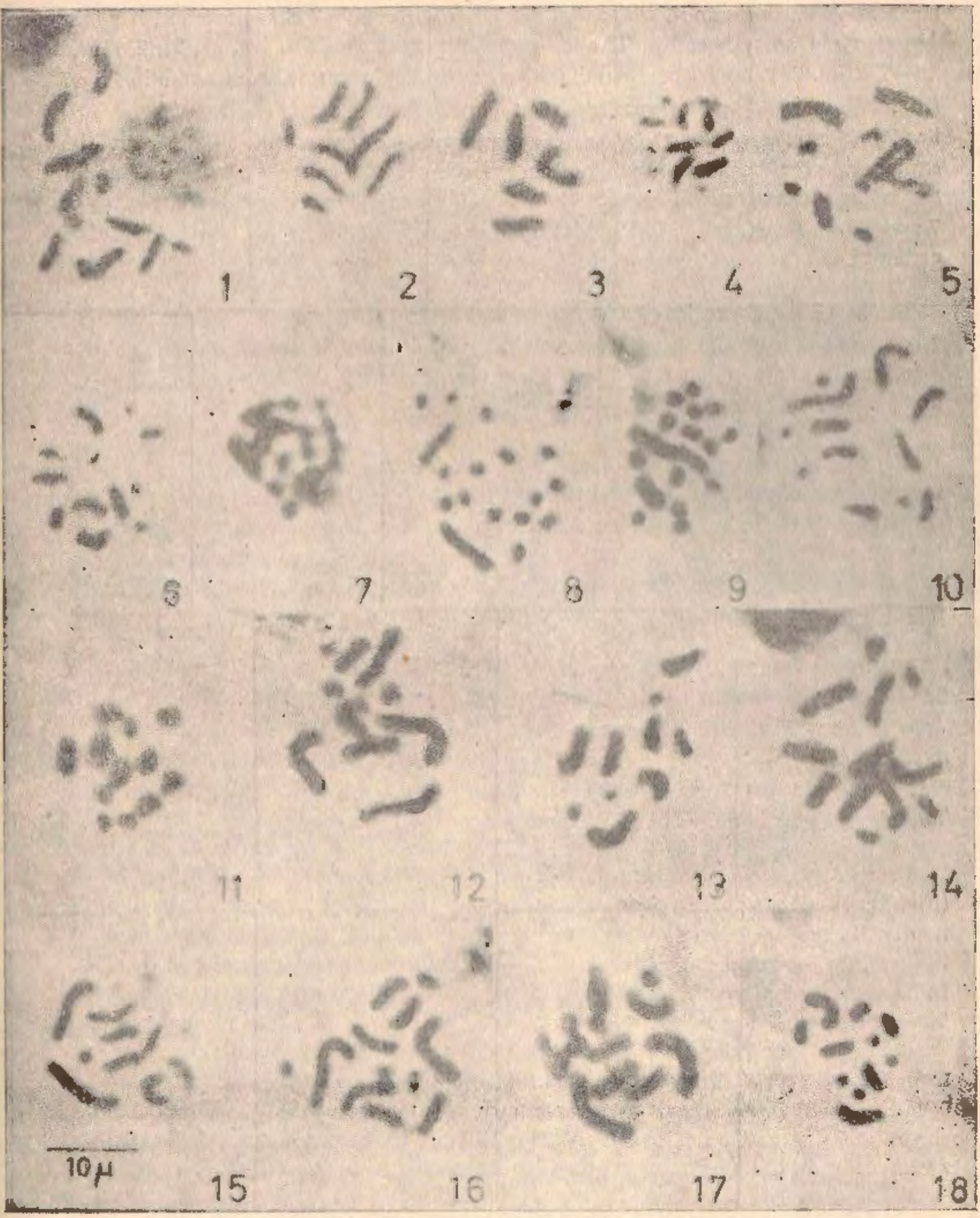
Table 1 lists diploid chromosome numbers for somatic cells of 22 species of Aphididae not previously karyotyped, alongwith their place of collection. Their idiograms representing karyotypes are drawn in Figs. 19-40. In the present study we have been able to study the chromosome numbers in the species under the subfamilies, Aphidinae and Lachninae. Aphids of other subfamilies could not be collected. The diploid chromosome numbers reported here range from 6 to 32.

The value of karyological investigation for aphid systematics has long been a constroversial question. Morgan (1905) after studying the karyotypes of three species of *Phylloxera*, concluded that there was no correlation whatsoever between the absolute chromosome numbers and the extramorphological specific characteristics of aphids. Shinji (1931) on the basis of analysing the karyotypes of 37 aphid species reached the opposite conclusion. The hypothesis now advanced is that karyological study of aphids can throw light on certain taxonomic problems (Sun and Robinson 1966).

Earlier chromosomal determinations have usually been based on a single sample of the parthenogenetic morphs of each aphid species (Kurl 1978, 1980 ; Khuda-Bukhsh 1980 ; Robinson and Chen 1969 ; Kuznetsova and Shaposhnikov 1973 ; Sun and Robinson 1966 ; Gut 1976 ; Kurl and Chauhan 1986). But later studies by Kurl (1986 b), Blackman (1980, 1986) using more than one samples for each species showed a great range of chromosomal variations within one sample of species. Variations in chromosome numbers were also observed if a particular species was collected from different host plants and even from different locality (Kurl 1986 b ; Blackman 1980, 1986). Aphids might be expected to show more variation of Karyotype within species than many other organisms for two reasons. Firstly they have holocentric chromosomes. Secondly they have thelytokous reproduction. These two factors seem to be the main reasons for chromosomal variation within species, the possibility for other reasons may not be ruled out. The chromosome numbers have undoubtedly undergone much more complicated evolutionary changes and in order to say with confidence which number of chromosomes was original one, it is essential to have cytological data which have been more strictly selected from the systematic point of view. It will probably be necessary first to study the karyotypes in the evolutionarily oldest groups of aphids.

The various diploid chromosome numbers so far recorded in the genus *Amphorophora* are 4, 12, 14, 18, 20, 21, 30, 48, and 72 (Kurl 1986 a). In the subspecies *A. ampullata bengalensis* the diploid numbers was found to be 12 (Fig. 1). It seems that 2n=12 is the basic number for the genus *Amphorophora* and other numbers might have evolved from this number.

Most aphid genera in fact show a remarkable constancy of chromosome number. Three out of five species of genus *Aphis* examined in the present study,



Figs. 1–18. Diploid chromosome numbers of aphids. 1. *Amphorophora ampullata bengalensis*, 2. *Aphis paraverbasci*, 3. *Aphis ruborum longisetosus*, 4. *Brachycaudus rumexicolens*, 5. *Capitophorus hippophaes mitegoni*, 6. *Hyperomyzus carduellinus*, 7. *Impatientinum asiaticum dalhousiensis*, 8. *Liosomaphis atra*, 9. *Macrosiphum miscanthi*, 10. *Metopolophium rubi*, 11. *Myzakkia verbasci*, 12 & 13. *Myzus cerasi umefoliae*, 14. *Myzus dycei*, 15. *Myzus obtusirostris*, 16. *Uroleucon pseudotenaceti*, 17 & 18. *Uroleucon simlaensis*.

have 2n=8 chromosomes, while *Aphis achyranthi* has 2n=7 chromosomes, it might be of male somatic cells. The idiograms for both 2n=8 (Figs. 21, 22, 23) and 2n=7 (Fig. 20) show some similarities except the largest chromosome in 2n=7 (Fig. 20), which may be regardsd as sex chromosome. *Aphis ruborum longisetosus* has 2n=6 chromosomes (Fig. 3). To explain it we have still to find out the explanation for the lesser number of chromosomes in the congeneric species. Under the genus *Aphis* all the 58 species show 2n=8 except 3 species which have 2n=6, 7 and 10 chromosomes. The modal number for the genus *Aphis* may be regarded as 2n=8.

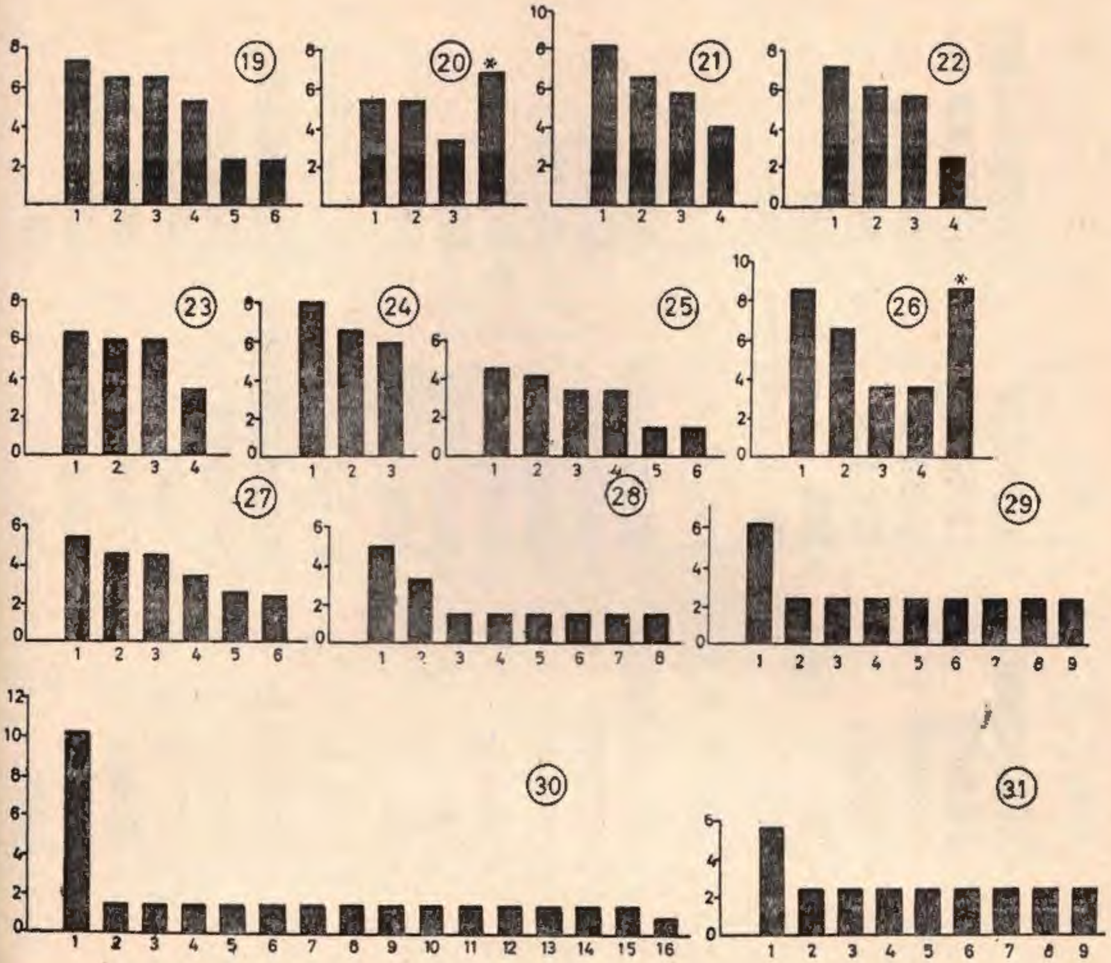
In all the 8 species of *Brachycaudus* known, the chromosomes numbers are 2n=12 (Kurl 1986 a). In *B. rumexicolens* the diploid chromosome number was also found to be 12 (Fig. 4). Thus there is a constancy in chromosome number here, at generic level.

The interesting feature of our study for *Capitophorus hippophaes mitegoni* is the presence of odd number of chromosomes (2n=9) (Fig. 5) in majority of the complements in the preparations. Three species out of 5 of the genus (Kurl 1986 a) have 2n=10 while only two have 2n=16. It appears that the basic number of chromosomes in the present genus might be 10 and the complements having 2n=9 might have come from male somatic cells.

In the case of *Hyperomyzus carduellinus* the diploid chromosome number is 2n=12 (Fig. 6), similar to that of other three species known so far (Kurl 1986 a). *Impatientinum asiaticum dalhousiensis* shows 2n=16 (Fig. 7) while *Indomasonaphis inulae* shows 2n= 32. It is clear from the idiogram (Fig. 30) that one pair of chromosomes is extraordinary large sized while others are very small in appearence. The biggest pair is more than five times bigger than the small ones.

In *Liosomaphis atra* the diploid chromosome number was observed as 18 (Fig. 8). In all the three species of *Liosomaphis* (including the present) the diploid number is 2n=18 (Kurl 1986 a) showing clear constancy in chromosome number in them. In *Macrosiphum miscanthi* the diploid chromosome number is 18 (Fig. 9). In 23 species of *Macrosiphum* worked out so far (Kurl 1986 a), 16 species possessed 2n=10 chromosomes, while others have 2n=8, 14 and 18. 2n=10 might be the basic number, for the genus *Macrosiphum* whereas other numbers have evolved from this number. In *Metopolophium rubi* the diploid chromosome number was found to be 12 (Fig. 10). All the five species of this genus have different diploid chromosome numbers i.e. 2n=10, 12, 14, 16 and 18 (Kurl 1986 a). In *Myzakkia verbasci* the diploid chromosome number was found to be 2n=12 (Fig. 11).

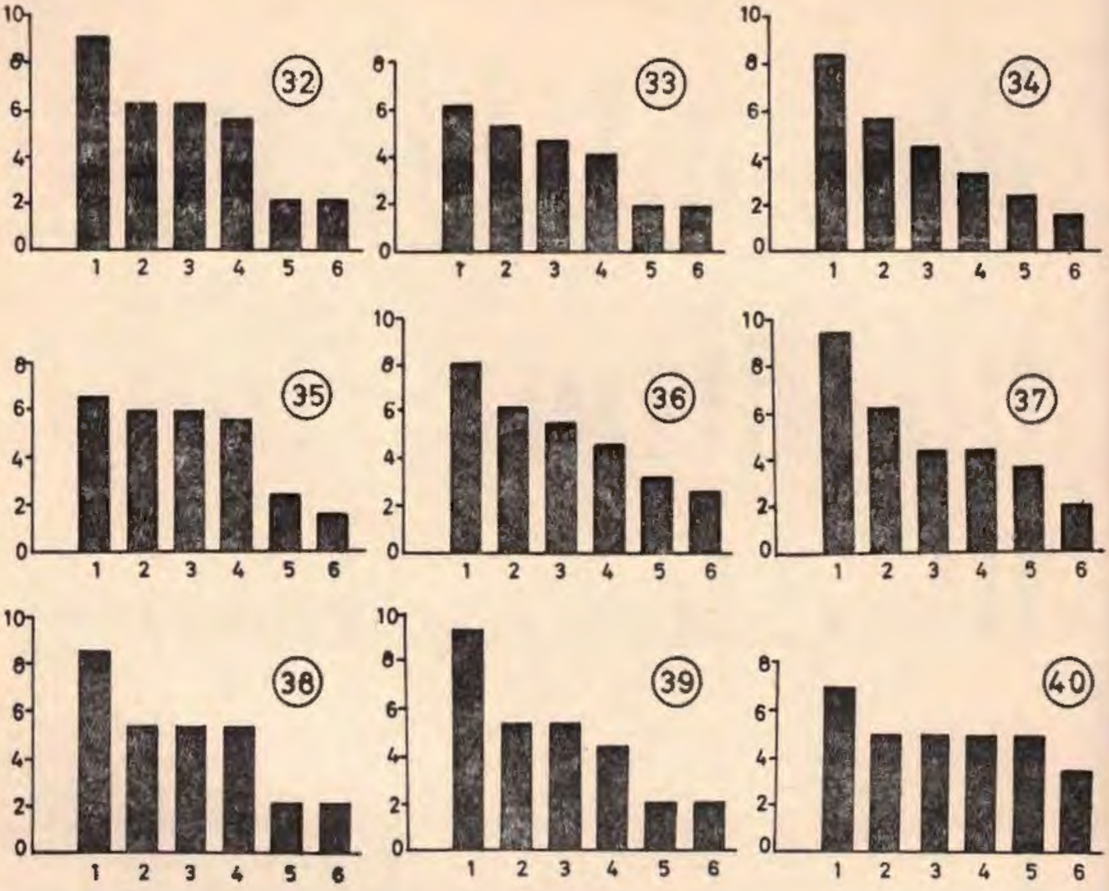
All the three species of *Myzus* investigated during the present study possessed 2n=12, similar to the modal number for this genus. The subspecies *Myzus cerasi umefoliae* has the normal diploid number as 2n=12 (Fig. 12). In the preparations the aneuploid complements having 2n=10 (Fig. 13) were also



observed. In *Myzus dycei* (Fig. 14) and *M. obtusirostris* (Fig. 15) the diploid chromosome numbers were found to be 2n=12. Majority of the species of this genus show 2n = 12 chromosome with some exceptions. The modal number for *Myzus* is very near to stability i.e. as 2n=12. However, variation in chromosome numbers within this genus does not always make taxonomic sense.

In the genus *Uroleucon*, most species have 2n=12 except a few, having 2n=8, 10 and 14. In *U. pseudotenaceti* the normal number is 2n=12 (Fig. 16) while in *U. simlaensis* besides the normal number 2n=12 (Fig. 17) whereas in some of the complements having 2n=11 (Fig. 18) were observed. In *U. sonchi* also normal number was 2n=12. It may be treated the modal number for this genus.

In the present study subfamily Lachninae is represented by *Cinara maculipes* having 2n=12 (Fig. 40) similar to majority of the species of this genus having 2n=12 (Kurl 1986 a).



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APHIDS AND THEIR COCCINELLID PREDATORS OF FRUIT TREES IN MANIPUR, NORTH EAST, INDIA

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SUMMARY

Eight aphid species under 6 genera infesting various fruit trees growing within the altitude of 300 m to 2000 m in Manipur, have been reported here. Notes on their appearance, nature of damage, seasonal incidence and thirteen species of coccinellid beetles predating on them have been provided.

INTRODUCTION

In Manipur 8 aphid species under 6 genera were found infesting various fruit trees growing within the altitude of 300 m to 2000 m. In the course of investigation 13 species of coccinellid predators were found predating different aphids.

Singh and Singh (1985) and Devi and Singh (1986) provided some works on aphidophagous coccinellids from the region, but none dealt on aphids and their coccinellid predators on fruit plants in Manipur.

MATERIAL AND METHODS

Aphids and their coccinellid predators were collected chiefly from the aerial parts of the infested fruit trees growing at different altitudes of Manipur. In the field, the aphids were preserved in 70% alcohol and their predators were kept in polythene bags. The larvae of predators were reared in the laboratory by grippling the particular aphid species. Everyday they were checked for the emergence of the adult ones. The aphids and the coccinellid predators were mounted and identified in usual manner.

RESULTS AND DISCUSSION

I. Subfamily : Aphidinae
Tribe : Aphidini

1. *Aphis gossypii* Glover : This aphid was found infesting *Artocarpus integrifolia*, *Psidium guyava* and *Pyrus malus* in the altitudes from 700 m to 2000 m, causing damages to the leaves and tender shoots during June to October. *Coccinella transversalis* Fabr., *Oenopia sexareata* (Mulsant), *Menochilus sexmaculatus* (Fabr.), *Oenopia kirbyi* Mulsant, *Oenopia guadripunctata* Kapur and *Scymnus* (*Pullus*) *hilaris* Motschulskey were found predating on this aphid.

2. *Hyalopterus pruni* (Geoffroy) : This aphid species was noticed infesting the leaves and tender shoots and causing curling of leaves of *Prunus amygdalus* and *Prunus persica* during the months of February and March throughout the

Manipur. Various coccinellid predators were found predating this aphid viz., *Coccinella septempunctata* L., *Cryptogonus bimaculatus* Kapur, *Cryptogonus guadriguttatus* Weise, *Menochilus sexmaculatus* (Fabr.), *Micraspis vincta* (Gorham), *Oenopia kirbyi* Mulsant, *Pania luteopustulata* (Mulsant), *Oonopia guadripunctata* Kapur and *Oonopia* sp. Among these, *O. quadripunctata* was found to be common.

3. *Rhopalosiphum nymphacae* (L.) : It infested the leaves and tender shoots of *Prunus amygdalus* during March to May throughout the Manipur and was predated by *Oenopia kirbyi* Mulsant and *Oenopia* sp.

4. *Toxoptera citricidus* (Kirkaldy) : This aphid infested the tender shoots and under surfaces of leaves of *Citrus grandis* throughout Manipur during March. The coccinellid predators collected from this aphid included *Cryptogonus bimaculatus* Kapur and *Menochilus sexmaculatus* (Fabr.).

5. *Toxoptera odinae* (v. d. Goot) : This aphid was collected from leaves of *Rust similiata*. *Coccinella septempunctata* L. was found predating this aphid.

6. *Toxoptera aurantii* (Boyer) : This aphid infested leaves, tender shoots and inflorescence of *Citrus aurantium* and *Magnifera indica* during September to April in many places of Manipur. *Menochilus sexmaculatus* (Fabr.) was the only predator of this aphid.

Tribe : Macrosiphini

7. *Myzus varians* Davidson : This aphid was found infesting the leaves of *Prunus amygdalus* during the period of February to May. The infested leaves of the host plant was found always curled. This aphid was predated by *Harmonia eucharis* Mulsant.

II. Subfamily : Greenideinae

Tribe : Greenideini

8. *Greenidea formosana heri* Raychaudhuri, Ghosh, Benerjee and Ghosh : This aphid was collected from the infested leaves and tender shoots of *Psidium guyava* and *Eugenia jambolana* in the plain and hilly areas of Manipur. *Menochilus sexmaculatus* (Fabr.) and *Platynaspis* sp. predated on this aphid.

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APHID FAUNA OF GARHWAL WITH SPECIAL REFERENCE TO THEIR DISTRIBUTION AND SEASONAL OCCURRENCE

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SUMMARY

The present paper is the outcome of the extensive ecological study of aphids of three districts of Garhwal during 1984—86. A total of 37 aphid species have been recorded, out of these 6 species have been observed to be new records for Garhwal Himalaya. Four phytogeographical zones are observed by the authors viz., tropical, subtropical, temperate and alpine zone. It has been observed that the subtropical zone is represented by rich aphid fauna, both qualitatively and quantitatively, when compared to the tropical, temperate and alpine zone. The seasonal occurrence of these insecte reveals that the subfamily Aphidinae has higher frequency of occurrence than the other subfamilies, Pemphiginae, Chaitophorinae, Drepanosiphinae, Greenideinae and Lachinae. Two peaks of population, the spring peak and the post monsoon peak have been observed in Garhwal.

INTRODUCTION

The importance of aphid fauna in agriculture, horticulture and forestry is well known. Although a great deal of work on the Aphididae of various parts of Indian subcontinent has been done (Agarwala and Ghosh 1984 ; David 1958 a ; Ghosh 1974 ; Ghosh and Raychaudhuri 1980, 1982 ; Misra and Kurl 1979) but little information is available on the species composition and ecology of Aphididae of Garhwal. The principal contributions are by Chakrabarti *et al.* (1985), Chakrabarti (1987), Chakrabarti and Raha (1985), Maity and Chakrabarti (1979, 1980), Maity *et al.* (1980), Medda and Chakrabarti (1986). Garhwal region is characterised by high and low mountain peaks, valleys, dense forests and cultivated lands covering the five districts viz., Tehri Garhwal, Pauri Garhwal, Uttarkashi, Chamoli and Dehradun.

The present study correlates the variations of aphid fauna of the three districts (Tehri, Pauri and Uttarkashi) with the ecological factors of altitude, climate and different flora. The distribution of aphids in these districts and their seasonal occurrence has also been recorded in the present investigation.

MATERIAL AND METHODS

The paper presents the results of two years (1984–1986) study, conducted at various stations and substations in three districts of Garhwal viz., Tehri, Pauri and Uttarkashi. The aphids were collected from different localities at various altitudes with their host plant and then preserved in 70% alcohol. The identification of the species were confirmed by Commonwealth Institute of Entomology, London. An altimeter (range 0–4500 m) was used to determine the altitudes of different localities. The incidence of occurrence at different zones are indicated by month(s) in roman numerals as shown in Table 1.

OBSERVATIONS

Observations on the species composition with their host plant alongwith the locality and seasonal occurrence of aphids in three districts of Garhwal are summarisd in Table 1. Table 2 shows the frequency of infestation by Aphididae on angiospermic plants while Table 3 presents the species composition of Aphididae in different phytogeographical altitudinal zones.

RESULTS AND DISCUSSION

Extensive survey during 1984–1986 revealed that the aphid fauna of three districts of Garhwal, is harboured by a total number of 25 plant families. Out of them 24 families are distributed over 51 angiospermic plant species while only one family of gymnosperm represented by *Thuja orientalis* which was observed to be infested by *Cinara tujafilina*. It is interesting to note that only three monocotyledon plant families (Araceae, Graminae and Scitaminae) were observed to harbour aphid species as evidenced by the occurrence of the aphids, *Pentalonia nigronervosa* on *Musa* sp. and *Colocasia* sp., *Rhospalosiphum maidis* on *Zea mays* and *R. padi* on *Bothriochloa* sp.. Cn the other hand there are 21 dicotyledon families which harbour maximum number of aphid species. These plant families are Rosaceae, Solanaceae, Leguminosae, Cucurbitaceae, Rutaceae, Asclepiadaceae, Compositae, Cruciferae, Myrtaceae, Rubiaceae, Acanthaceae, Scrophulariaceae, Salicaceae, Polygonaceae, Berberidaceae, Urticaceae, Magnoliaceae, Sapindaceae, Cupuliferae, Anacardiaceae and Malvaceae. Out of 21 families mentioned above the first 12 were infested by *Aphis* spp. alone. Moreover, out of these 12 families Rosaceae, Leguminoceae, Cucurbitaceae, Solanaceae and Rutaceae harbour maximum population of *Aphis* spp. than the other plant families.

Table 2 reveals that among the angiospermic plants the dicotyledon families (23) harbour maximum number of aphid species than the monocotyledons. Among the gymnospermic plants only one family (Cupressaceae) was represented to harbour aphid species.

The qualitative studies (Table 1) revealed that the most abundant group of aphids in Garhwal is the subfamily Aphidinae. The subfamilies Pemphiginae, Chaitophorinae, Drepanosiphinae, Greenideinae and Lachinae occupy next position in decreasing order of occurrence. Thus the subfamily Aphidinae appears to be the most successful group in this region. Similar observations were made by Agarwala and Raychaudhuri (1981) on the aphids of Sikkim. Their study shows

TABLE 1. Seasonal occurrence and distribution of aphids during 1984–86 in three districts of Garhwal.

Sl. No. (1)	Aphid species (2)	Host plant (3)
	Family : Aphididae Subfamily : Aphididae	
1.	**Acyrthosiphon pisum* (Harris)	*Pisum* sp.
2.	*Aphis citricola* van der Goot	*Zanthoxylum alatim*, *Eupotarium* sp.
3.	*A. craccivora* Koch	*Vigna sinensis*, *Dolichos lablab*
4.	*A. fabae* Scopoli Group	*Solanum nigrum*, *Cestrum* sp.
5.	*A. fabae solanella* Theobald	*Solanum nigrum*
6.	*A. gossypii* Glover	*Psidium guajava*, *Cyphomendra* sp., *Cucumis sativus*, *Cucurbita* spp., *Raphanus sativus*, *Citrus* spp., *Capsicum annuum*, *Luffa cylindrica*, *Strobilanthus* sp., *Hamiltenia* sp.
7.	*A. nerii* Boyer d. F.	*Calotropis procera*
8.	*A. ruborum longisetosus* A. N. Basu	*Rubus ellipticus*
9.	*A. verbasci* Schrank	*Verbascum chinensise*, *V. thapsus*
10.	*Brevicoryne brassicae* (L.)	*Raphanus sativus*, *Brassica* sp.
11.	*Hysteroneura setariae* (Thomas)	*Chyrsanthemum* sp., *Triticum vulgarae*, *Eleusine coracana*
12.	*Liosomaphis atra* Hille Ris Lambers	*Berberis aristata*
13.	*L. himalayansis* A. N. Basu	*Berberis aristata*, *Fagopyrum* sp.
14.	*Lipaphis erysimi* (Kalt.)	*Brassica* spp., *Raphanus sativus*, *Urtica* sp.
15.	*Macrosiphoniella pseudoartemisiae* Shinji	*Artemisia vulgaris*. *Rosa* sp.
16.	*M. sanborni* (Gillette)	*Chrysanthemum* sp.
17.	**Macrosiphum euphorbiae* (Thomas)	*Citrus aurentifolia*
18.	*M.* (*Sitobion*) *rosaeiformis* Das	*Rosa* spp.
19.	**Melanaphis pahanensis* (Takahashi)	*Prunus communis*

TABLE I. Continued

Locality+ surveyed (4)	Distribution and seasonal occurrence (5)			
	Upto 900 m	900–2000 m	2000–3600 m	3600–5500 m
TH	III, IV	III		
UK NT CS AJ PR KN		II–IV, VIII–IX	III, VII	
TH KD NT UK UD SR SP	IX–XI	VII–XII		
NT KN GH	III, IV	IX, X		
UD KD TH PR KN AJ KT NT UK NL MN CS JO KA TP	II–V, VIII–IX	II–V, VII–XII	II–V, VII–XII	
TH KD PR UK NT AJ PN JO BP SR NL KR	II–V, VIII–IX	II–XI		
TH KD	II–VII			
TH NT CH DD AJ UK NL BT BP	I–IV, VII–IX	I–V. IX–XI		
NT DD BP BG AJ UK JO KA	IV, VI	IV, VI, VIII–IX		
TN CH UK	VIII	VIII–X		
CH PR	III–IV	IV, VIII, XI		
NT KT AJ		II, VI, IX–X	II, VI, VII–X	
—do—		—do—	—do—	
TH NT SR PR DD DS BP NL KK PN KD BG UK JO BT JP CG PN SP UD MN CS	I–XII	I–XII	II–V, VII–XII	
TH GH BP CG PR UK	II–V	II–V, VIII–XI	III, IV	
UK AJ CH PR JO	III–IV	IV, VIII–XI		
AJ UK PR JO		X–XI		
AJ SR DD BT CS TH NT PR UK JO MN KN	II–IV, XI	II–XII	I–XII	
BT		VIII–X		

TABLE I. Continued

Sl. No. (1)	Aphid species (2)	Host plant (3)
20.	*M. sacchari* (Zehntner)	*Saccharum officinarum*
21.	*Myzus dycei* Carver	*Urtica dioica*
22.	*M. persicae* (Sulzer)	*Rosa* spp., *Raphnaus sativus*, *Solanum nigrum*, *S. tuberosum*, *S. melongena*, *Malva sylvestris*, *Nicotina tabacum*, *Lycopersicum esculantum*, *Prunus persica*, *Brassica* sp.
23.	**Pentalonia nigronervosa* Coquerel	*Musa* sp., *Colocasia* sp.
24.	*Phorodon cannabis* Passerini	*Cannabis sativa*
25.	*Rhopalosiphum maidis* (Fitch)	*Chrysanthemum* sp., *Zea mays*, *Eleusine coracana*
26.	*R. padi* (L.)	*Dolichos* sp., *Zea mays*, *Eleusine coracana*, *Bothriachloa* sp.
27.	**Sinomegoura citricola* (van der Goot)	*Vigna sinensis*, *Smilex* sp.
28.	*Toxoptera aurantii* (Boyer de Fonscolomble)	*Cestrum* spp., *Michelia champaka*, *Mangifera indica*, *Prunus* spp.
29.	*T. citricidus* (Kirkaldy)	*Citrus aurantifolia*
	Subfamily : Pemphiginae	
30.	*Epipemphigus imaicus* (Cholodkovsky)	*Populus ciliata*
31.	*Eriosoma lanigerum* (Hausmann)	*Pyrus malus*
32.	*Pemphigus mordvilkoi* Cholodkovsky	*Populus ciliata*
	Subfamily : Chaitophorinae	
33.	*Periphyllus pallidus* Chakrabarti and Mondal	*Acer acuminatuum*
34.	*P. villosii* Chakrabarti	*Acer acumintuum*
	Subfamily : Drepanosiphinae	
35.	*Betacallis prunicola* Basu, Ghosh and Raychaudhuri	*Prunus ceracoides*
	Subfamily : Greenideinae	
36.	*Greenidea* (*Trichosiphum*) *kumaoni* Chakrabarti	*Quercus* sp.
	Subfamily : Lachinae	
37.	**Cinara tujafilina* (der Guercie)	*Thuja* spp.

+ Abbreviations of localities : *Tehri Garhwal* : AJ–Anjanisain, BG–Bhagwatpur, BP–Bhagirathipuram, CG–Chopriyalgaon, CH–Chamma, GH–Ghansali, GN–Gangi, GU Ghuttu, JP–Jaripani, KA–Kaddukhal, KD–Kandal, KK–Kandikhal, KL–Khatling, KT–Kanatal, NT–New Tehri, NL–Nail, PK–Paukhal, PN–Pratapnagar, RH–Reeh, TH–Tehri and TP–Tipiri.

TABLE 1. Continued

Locality+ surveyed (4)	Distribution and seasonal occurrence (5)			
	Upto 900 m	900-2000 m	2000-3600 m	3600-5500 m
UK		VIII-IX		
NT CH CG UK JO	II-V	II-V, VIII-XII		
NH PK PR SP UK TH AJ CT BF BP SR CS DS DD TP MN GN GU KR TP	III-XI	I-V, VIII-XI	III, IV	
PK PR		VIII-X		
UK GN PR JO		VIII-XI		
CH NT UK AJ PR BT BP PK	III, VIII	III-V, VII-XI		
TH PR UK JO NL	VIII	II, XII		
BP DD	VIII-IX	VIII-IX		
UK TH PR	III	VIII-XI		
AJ PR UK BT PK CH JO	III	II-V, VIII-XI	X	
CG KT			III-XI	
CG KT			III-XI	
DH PR KT CH BT JP PN		I-XII	I-XII	
KL				IX
KL				IX
NT CG PR PK UK BT JO AJ GU		I-III, VIII-XI	VIII-XI	
AJ NT PR		IV-VIII	IV-IX	
TH PR UK DD AJ NT PK OJ BP CH	II-V, VI-XI	I-XIII	I-XII	

Pauri Garhwal : KR-Kherakhal, KN-Kandolia, PR-Pauri, SR-Srinagar (Garhwal), SP-Satpuli and UD-Uphalda.
Uttarkashi : BT-Bhatwari, CS-Chiniyalisaur, DD-Dunda, GS-Gyansu, DS-Dharasu, JO-Joshiyara, MN-Maneri and UK-Uttarkashi.
+ January to December=I to XII

TABLE 2. Erequency of infestation by aphids (Aphididae) on various groups of plants.

Subfamily	Infested plant groups		
	Angiosperm		Gymnosperm
	Monocotyledon	Dicotyledon	
Aphidinae	3	18	—
Pemphiginae	—	2	—
Chaitophorinae	—	1	—
Drepanosiphinae	—	1	—
Greenideinae	—	1	—
Lachinae	—	—	1
Total	3	23	1

TABLE 3. Distribution of aphids (Aphididae) in different zones.

Subfamily	Species composition			
	Tropical zone upto 900 m	Subtropical zone 900-2000 m	Temperate zone 2000-3600 m	Alpine zone 3600-5500 m
Aphidinae	21	28	10	—
Pemphiginae	1	1	3	—
Chaitophorinae	—	—	—	2
Drepanosiphinae	—	1	1	—
Greenideinae	—	1	1	—
Lachinae	—	1	1	—
Total	22	32	16	2

that the subfamily Aphidinae is capable of adapting to a wide range of ecological parameters like temperature, rainfall and humidity at different altitudes. The subfamily Aphidinae is distributed over 21 angiospermic plant families (18 dicotyledon and 3 monocotyledon). These plant families distributed over 20 aphid genera including 29 species. It is interesting to note that out of 37 species identified so far, 6 species (marked with asterisk in Table 1) are being recorded for the first time from Garhwal Himalaya.

Majority of aphid species specially those belonging to subfamily Aphidinae were observed to be polyphagous while a few species were found to be monophagous being restricted to the single host plant species. The polyphagous species include the predominent forms such as *Myzus persicae*, *Aphis gossypii*, *A. citricola*, *A. fabae*, *A. craccivora*, *A. verbasci*, *Lipaphis erysimi*, *Brevicoryne brassicae*, *Macrosiphoniella pseudoartemisiae*, *Rhopalosiphum maidis*, *R. padi*, *Liosomaphis himalayansis*, *Pentalonia nigronervosa*, *Sinomegoura citricola*, *Toxoptera aurantii* and *Hysteroneura setariae*. Agarwala and Ghosh (1985) reported *Aphis* *gossypii*, *A. fabae*, *Brachycaudus helichrysi*, *Myzus persicae*, and *Toxoptera aurantii* as highly polyphagous species. On the contrary, the monophagous species may include *Cinara tujafilina*, *Eriosoma lanigerum*, *Pemphigus mordvilkoi*, *Epipemphigus imaicus*, *Greenidea* (*Trichosiphum*) *kumaoni*, *Melanaphis sacchari*, *Betacallis prunicola*, *Periphyllus villosii* and *P. pallidus*. Moreover, the gall forming aphid species produce galls on various parts of the host plant may be called as host specific. The stem and leaf galls were observed on *Populus ciliata* caused by *Pemphigus mordvilkoi* and *Epipemphigus imaicus* respectively.

Altitudinal and Seasonal Occurrence:

From the vertical distributional point of view Garhwal region may be divided into four phytogeographical zones viz., tropical (upto 900 m), subtropical (900–2000 m), temperate (2000–3600 m) and alpine (3600–5500 m). These zones correspond to the arbitrary altitudinal zones as observed by Chakrabarti (1981).

Table 3 shows that the subtropical zone has the highest number (32) of aphid species (44·4%) with higher frequency of occurrance represented by 5 subfamilies, when compared to 22 species (30·6%) belonging to 2 subfamilies from tropical zone ; and 16 species (22·2%) represented by 5 subfamilies from temprate zone. So the subtropical zone may be called as the most productive zone. Tables 3 and 1 show that the aphid fauna at alpine zone is rare both in quality and quantity as represented by only 2 species (2·8%) belonging to subfamily Chaitophorinae. Maity *et al.* (1980) recorded 2 species from extreme high altitude (3600–5500 m). This shows that aphid fauna of higher altitudes (above 3000 m) is affected adversely both in quantity and quality. The alpine zone may be called as rare zone. The phytogeographical distributional pattern indicates that the 5 subfamilies viz., Aphidinae, Pemphiginae, Drepanosiphinae, Greenideinae and Lachinae are only represented in subtropical and temperate zones (Table 3).

Most of the aphid species do not show their occurrence throughout the year in all seasons but a few species such as *Eriosoma lanigerum*, *Cinara tujafilina*, *Lipaphis erysimi* and *Macrosiphum* (*Sitobion*) *rosaeiformis* were observed through out the year and thus adaptable to a wide range of ecological parameters such as temperature and altitude.

General observation revealed that the population of aphids in Tehri, Dhanolti, Pauri and Uttarkashi (640–2350 m) is increased (during March–April) when new buds start to appear on the host plants. This is followed by a slight decrease in population due to increase in atmospheric temperature (17°C–40°C) during May–June. The abundance of aphids again increase during the post-monsoon period (September–October) which is followed by a sudden decrease due to severe cold during December–January (6°C–21°C). Thus two peaks of population are built in a year, spring peak and post-monsoon peak. The present observations are in close agreement with Ghosh (1975) who recorded February–March as the period of maximum population of aphids in Calcutta and its suburb.

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RECORDS OF APHID PARASITOIDS FROM TERAI BELT OF EASTERN UTTAR PRADESH–I

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SUMMARY

Survey for hymenopterous parasitoids attacking aphids have been conducted in Terai belt of Eastern U. P. during 1986 and 1987. Seven species of aphid parasitoids viz., *Aphidius matricariae* Haliday, *A. uzbekistanicus* Luzhetzki, *Lipolexis scutellaris* Mackauer, *Lysiphlebia mirzai* Shuja-Uddin, *Lysiphlebus delhiensis* (Subba Rao and Sharma), *Praon* sp., *Trioxys* (*Binodoxys*) *indicus* Subba Rao and Sharma have been recorded from this region. *A. matricariae* and *Praon* sp. are reported for the first time from this area.

INTRODUCTION

The Eastern Uttar Pradesh has remained completely virgin area where it concerns parasitoids of aphids. This preliminary information from Terai belt of Eastern U. P. would provide data about the availability of these potential biagents. Earlier, the fauna of aphid parasitoids of Western Uttar Pradesh was studied by Shuja-Uddin (1975). Recently Singh and Tripathi (1987) recorded hyperparasitism in two species of aphid parasitoids. In the present study four new host associations are also recorded as mentioned in the Table 1.

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TABLE 1.

Name of Parasitoid (1)	Place of collection (2)	Date of collection (3)	Host (Aphid) (4)	Host plant (5)
Aphidius matricariae Hal.	Parasia (Deoria)	20·III·87	*Myzus persicae* (Sulz.)	*Lycopersicon esculentum*
A. uzbekistanicus Luzh.	Gopalapur (Gorakhpur)	11·III·87	*Macrosiphum (Sitobion) avenae* (Fabr.)	*Triticum aestivum* *Hordeum vulgare*
Lipolexis scutellaris Mack.	Parasia (Deoria)	28·XI·86	*Aphis gossypii* Glover	*Capsicum frutescens*
	—do—	25·XI·86	*A. craccivora* Koch	*C. frutesens*
	—do—	02·III·87	*M. (S.) avenae* (Fabr.)	*H. vulgare*
	University campus	02·I·87	*M. persicae* (Sulzer)	*Solanum melongena*
Lysiphlebia mirzai Shuja-Uddin	Gopalapur (Gorakhpur)	06·II·87	*Hylopterus pruni* (Geoff.)	*Phragmites karka*
Lysiphlebus delhiensis (Subba Rao and Sharma)	University Campus	03·II·87	*Rhopalosiphum maides* (Fitch)	*Pemisetnm typhoides*
Praon sp.	Parasia (Deoria)	02·III·87	*M. (S.) avenae* (Fabr.)	*H. vulgare*
Trioxys indicus Subba Rao and Sharma	(Deoria)	28·XI·86	*A. gossypii* Glover	*C. frutescens* *Luffa cylindrica* *S. melongena*
	—do—	25·XI·87	*A. craccivora* Koch	*Lagenaria vulgaris* *Dolicros lablab* *Cajanus cajan*
	University Campus	02·I·87	*M. persicae* (Sulzer)	*S. tuberosum*

TABLE 1. Continued

Parasitisation (%) (6)	Distributiof Parasitoid/ (Reference) (7)	Remarks (8)
15%	Kashmir (Stary and Bhagat 1978) Manipur (Singh and Singh 1986) Meghalaya (Stray and Ghosh 1975) Sikkim (Agarwala *et al.* 1980)	First record of the parasitoid from U.P.
45%	Kashmir (Stary and Bhagat 1978) Sikkim (Agarwala *et al.* 1980) Uttar Pradesh (Shuja-Uddin 1975)	
27%	All over India (Stary and Ghosh 1983)	*M.* (*S.*) *avenae* is a new host record of this parasitoid.
10%		
8%		
35%		
12%	U. P. (Shuja-Uddin 1975)	*H. pruni* is a new host record of this parasitoid. Earlier, only *Melanaphis sacchari* (Zehn.) was record as its host (Shuja-Uddin 1975).
87%	Assam (Ramaseshiah and Menon 1971) Punjab (Subba Rao and Sharma 1960) U. P. (Singh and Tripathi 1987)	*R. maidis* is a new host record of this parasitoid. Earlier, *M. sacchari* and *M. indosacchari* (David) were record as its hosts.
10%	Kashmir (Singh and Bhagat 1978) Meghalaya (Stary and Ghosh 1978)	First record of the parasitoid from U. P. *M.* (*S.*) *avenae* is a new host record of this parasitoid.
8% 40% 65% 47% 32% 87% 28%	All over India	

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IDENTIFICATION OF *BRASSICA* GENOTYPES LEAST SUSCEPTIBLE TO MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.)

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SUMMARY

A number of *Brassica* genotypes were evaluated for three years for their susceptibility to mustard aphid, *Lipaphis erysimi* (Kalt.) attack under field conditions. The results showed that six genotypes namely *Brassica nigra* (tall), RLM-29, RLM-29/25, RLM-84, RLM-171 and P-11/7-1 were least susceptible to aphid attack consistently for three years.

INTRODUCTION

Mustard aphid, *Lipaphis erysimi* (Kaltenbach) is the most serious insect pest of rapeseed mustard crop. Although effective chemical control measures to keep the pest under check are known (Hazarika and Saharia 1981 ; Bakhetia and Brar 1982 ; Bhadoria *et al.* 1982), yet built-in resistance in the plant against the pest is an important mechanism and an integral part of a pest management programme. It is reported that in general *Rai* varieties were relatively less susceptible to aphid attack than yellow and brown sarson varieties (Prasad and Phadke 1980 ; Singh *et al.* 1982 ; Bakhetia *et al.* 1984 ; Prasad and Phadke 1984). The present paper is a further contribution on the susceptibility of various *Brassica* genotypes to mustard aphid attack.

MATERIAL AND METHODS

The experiments were carried out at the farm of the Indian Agricultural Research Institute, New Delhi during the *rabi* season from 1977-78 to 1980-81. During 1977-78 to 1979-80, thirty genotypes and during the period from 1978-79 to 1980-81, thirty five genotypes in another lot were separately evaluated. The seeds were obtained from different locations through oilseed breeders. The experiment was laid out in each year in a randomised block design with three replications. Sowings were done in a 3m row length on 22nd, 24th, 23rd and 25th October of each year respectively. Row to row distance was 60 cm and plant to plant 20 cm. Recommended agronomic practices were followed for raising the crop.

The genotypic response to aphid attack was evaluated on the basis of aphid infestation index (A. I. I.). For this purpose, ten plants in a row were given grades ranging from zero to five as suggested by Bakhetia and Sandhu (1973). Zero grade indicated plants free from aphid infestation and showing excellent growth, one with very few aphids but with normal plant growth, two with plants having low infestation and average growth, three with plants having high infestation and growth below average, four with plants having very high infestation and poor growth and five with plants covered with aphids on all parts and with stunted growth.

Observations were recorded each year from the middle of January and repeated after every ten days. Thus each year, three or four observations were recorded from each replicate from which overall A. I. I. was estimated.

RESULTS AND DISCUSSION

Results on the response of different genotypes in terms of A. I. I. are given in Tables 1 and 2. In order to have rigrous screening, genotypes were compared at 1 percent critical difference only. The following genotype(s) were found to be significantly least susceptible in the respective three years of study :

(i) Genotypes from amongst Table 1.

1977–78 — *Brassica nigra* (tall), *B. nigra* (dwarf) and T–6342.

1978–79 — *B. nigra* (tall).

1979–80 — *B. nigra* (tall).

(ii) Genotypes from amongst Table 2.

1978–79 — *B. nigra* (tall), RLM-240, RLM-171, RLM-84, RLM-574, RLM-29/25, P-11/7–1, RLM-137 and RLM-29.

1979–80 — *B. nigra* (tall), RLM-240, RLM-171, RLM-84, RLM-29/25, P-11/7–1, RLM-137, RLM-29, RLM-105, RLM-188 and RLM-603.

1980–81 — *B. nigra* (tall), RLM-171, RLM-84, RLM-29/25, P-11/7–1, RLM-29, KB-2, RLM-603, YSK-742, Composite-1, DBS–1 and DYS-1.

The above results thus show that in all only six genotypes namely *B. nigra* (tall), RLM-29, RLM-29/25, RLM-84, RLM-171 and P-11/7–1 were least susceptible to aphid attack consistently for three years. Some of the genotypes which were least susceptible in one year did not give the same response in another year. This may be due to difference in the intensity of aphid attack and C. D. values.

TABLE 1. Relative susceptibility oi *Brassica* genotypes of *L. erysimi* in different years.

S.No.	Genotype	Overall aphid infestation index		
		1977–78	1978–79	1979–80
1.	*B. nigra* (Tall)	0·42	0·85	1·43
2.	*B. nigra* (dwarf)	0·52	1·03	1·62
3.	T–6342	0·62	1·13	1·97
4.	RH–30	0·79	1·47	2·15
5.	Varuna	0·84	1·73	2·53
6.	RLM–198	0·85	1·54	2·02
7.	R–75–1	0·90	1·50	1·98
8.	Prakash	1·20	1·14	1·84
9.	Pusa bold	1·08	1·86	2·41
10.	T–9 (Kanpur)	1·19	2·02	2·46
11.	B–85	1·27	1·72	2·68
12.	Pusa Kalyani	1·41	2·01	2·23
13.	YSS–24	1·42	2·14	2·07
14.	YSS–8	1·43	1·51	3·04
15.	BS–113	1·49	1·87	2·43
16.	BSIK–1	1·49	1·82	2·21
17.	BSPH–28	1·51	1·75	2·56
18.	BSIK–84–63	1·52	1·64	2·30
19.	BSH–1 (Hissar)	1·55	2·11	2·41
20.	GSM	1·63	2·22	2·13
21.	YS–Pb–24	1·73	1·71	2·77
22.	BSH–1 (Kanpur)	1·79	1·87	2·67
23.	B–54	1·83	2·96	3·17
24.	YS–B–9	1·99	2·39	3·01
25.	YS–74–2	2·05	2·02	3·13
26.	M–27	2·05	2·78	3·41
27.	T–9 (Hissar)	2·17	2·46	2·49
28.	BSIK–6	2·33	2·50	3·05
29.	Sangam	2·48	2·93	3·52
30.	YS–74–1	2·88	1·97	2·23
	CD at 1%	0·23	0·15	0·16
	S. Em ±	0·85	0·56	0·61

TABLE 2. Relative susceptibility of *Brassica* genotypes of *L. erysimi* in different years.

S.No.	Genotype	Overall aphid infestation index		
		1978–79	1979–80	1980–81
1.	*B. nigra* (Tall)	1·12	1·46	1·15
2.	RLM–240	1·28	1·89	1·71
3.	RLM–171	1·32	1·75	1·53
4.	RLM–84	1·39	1·45	1·37
5.	RLM–514	1·42	2·08	1·73
6.	RLM–29/25	1·45	1·81	1·51
7.	P–11/7–1	1·48	1·82	1·54
8.	RLM–137	1·52	1·70	1·74
9.	RLM–29	1·57	1·78	1·48
10.	RLM–105	1·63	1·81	1·65
11.	RLM–188	1·72	1·69	1·69
12.	KB–2	1·77	2·30	1·59
13.	RW–85–89	1·78	2·28	1·66
14.	RW–15	1·83	2·50	2·30
15.	RLM–821	1·87	2·16	1·90
16.	RLM–603	1·87	1·75	1·62
17.	YSIK–742	1·97	2·84	1·63
18.	K–1	1·98	2·30	1·68
19.	Composite–I	2·00	2·02	1·58
20.	Varuna	2·30	2·32	1·65
21.	DBS–1	2·04	2·93	1·60
22.	DBS–2	2·17	2·41	2·61
23.	YS–1–42	2·19	3·24	1·83
24.	DYS–1	2·36	2·85	1·50
25.	YSIK–741	2·39	3·25	1·79
26.	T–36	2·47	3·15	2·00
27.	TW–8/12	2·48	3·47	2·45
28.	DYS–2	2·56	2·81	1·68
29.	Assam Mass Selection	2·73	3·58	2·03
30.	TW–19/43	2·81	3·28	2·58
31.	DS–17–MD	2·88	3·72	2·58
32.	TW–8/21	2·90	3·33	2·31
33.	TW–1/14	2·93	3·59	2·35
34.	TW–8/4	3·24	3·47	2·20
35.	TW–2/8	3·59	3·11	2·47
	CD at 1%	0·48	0·49	0·49
	S. Em ±	0·12	0·13	0·13

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CARBOHYDRATES IN THE HONEYDEW OF *RHOPALOSIPHUM NYMPHAEAE* (L.)

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SUMMARY

The carbohydrate composition of honeydew excreted by *Rhopalosiphum nymphaeae* (L.) and that of the sap of its host plant, lotus (*Nelumbium speciosum*) was determined by paper partition chromatography. The honeydew contained glucose, sucrose, fructose, maltose, melezitose and glucose–1–Phosphate whereas lotus extract contained glucose, sucrose, fructose and glucose–1–Phosphate. The principal sugar in honeydew was melezitose, a trisaccharide which was absent in the plant extract.

INTRODUCTION

The composition of honeydew has been the subject of many studies. Early gross analysis by standard analytical methods revealed that water, nitrogen and certain carbohydrates are the main constituents of aphid honeydew (Molliard 1931 ; Maltais and Auclair 1952).

The use of paper chromatography has made it possible to study the chemical composition of minute amounts of honeydew which reported to contain carbohydrates, appreciable quantity of amino acids and other organic compounds. Analysis of honeydew contributes to a better understanding of the intermediary metabolism and nutritional needs of the aphid.

In the present paper an attempt has been made to study the carbohydrate composition of honeydew of *Rhopalosiphum nymphaeae* (L.) which feeds on lotus.

MATERIALS AND METHODS

Qualitative study was made by paper partition chromatography. The procedure was followed after Malpress and Morrison (1949), Chargaff *et al.* (1948) and Patridge (1949). Glucose and maltose were identified by aniline hydrogen phthalate reagent. Fructose, sucrose and melezitose were identified by 2–4 dinitrophenyl hydrazine spray.

RESULTS AND DISCUSSION

The results on the analysis of honeydew of *R. nymphaeae* are presented in Fig. 1. It can be seen from the figure that the honeydew of *R. nymphaeae* contains glucose, sucrose, fructose, maltose, melezitose and glucose–1–Phosphate

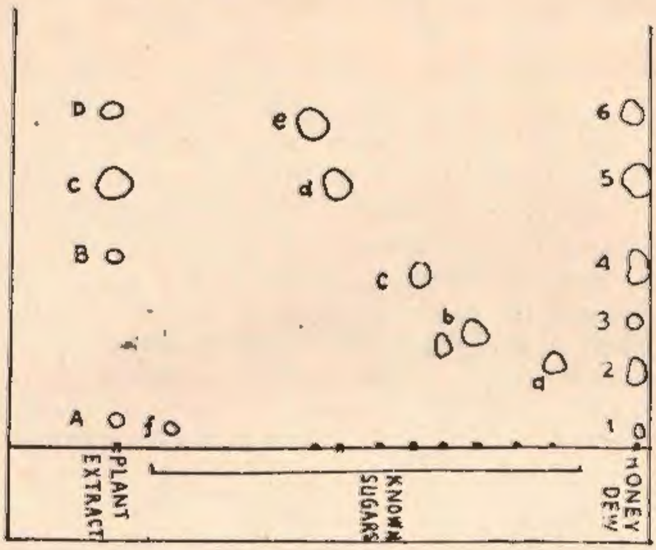

Fig. 1. Chromatograms showing carbohydrate components of honeydew of *R. nymphaeae* (L.) and Lotus extract.

1–Glucose-1-Phosphate	a–Melezitose	A–Glucose-1-Phosphate
2–Melezitose	b–Maltose	B–Sucrose
3–Maltose	c–Sucrose	C–Glucose
4–Sucrose	d–Glucose	D–Fructose
5–Glucose	e–Fructose	
6–Fructose	f–Glucose-1-Phosphate	

whereas plant extract contains glucose, sucrose, fructose and glucose–1–Phosphate. Of special interest is the glucose spot which is relatively larger in comparison to other sugars. It appears that glucose is present in relatively large amount.

The qualitative analysis of both plant, sap extract and honeydew of *R. nymphaeae* revealed virtually identical carbohydrates, the most common in both being glucose, sucrose, fructose and glucose–I–phosphate which have also been recorded from other aphids and coccids (Gray 1952 ; Gray and Fraenkel 1953, 1954). In the honeydew of *R. nymphaeae* some additional carbohydrates such as maltose, melezitose and some unidentified non-reducing oligosaccharides were also noticed which are very complex in composition. Duspiva (1954) recorded maltosyl fructofuranose (an oligosaccharide) from the honeydew of *Aphis pomi* and *Eriosoma lanigerum*.

The amount of glucose and sucrose in the honeydew of *R. nymphaeae* as determined by the relative intensity of the coloured spots on the chromatograms, are found to be considerably lower than that present in the plant extract. It is important to note that glucose and sucrose are the main constituents among the dietary sugars utilized maximum by aphids (Baron and Gutherie 1960). It is believed that the aphid removed the reducing sugars and converted them into non-reducing oligosaccharides through some metabolic processes. The fact that the oligosaccharides are never found in the plant extract, suggests them to be waste metabolic products. On the other hand, considerable amount of these sugars present in honeydew are said to be transitory intermediate products formed during hydrolysis of dietary sucrose and these are purposefully synthesized within the insect body (Ewart and Metcalf 1956), although the significance of this chemical change remained obscure (Mittler 1958). The possibility that intracellular microorganisms which occur in the midgut epithelium of aphids (Schanderl *et al.* 1949) or the enzymes which occur in plant sap (Zimmermann 1957) may be responsible for this change, can not be ruled out.

In *R. nymphaeae* the present authors failed to find fructomaltose which was obtained by Gray and Fraenkel (1953) and White and Maher (1953). The chromatographic solvent might hydrolyse fructomaltose to fructose and maltose. The presence of this in the honeydew and not in the food plant, demonstrates that honeydew is, at least in part, a digestive product. This conclusion is further substantiated by the appearance of uric acid in the honeydew of *R. nymphaeae*. It is believed that fructomaltose is an intermediate product formed during the action of the gut enzyme invertase on sucrose (Gray and Fraenkel 1953).

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APHIDS (HOMOPTERA : APHIDIDAE) AND THEIR ASSOCIATED ANTS (HYMENOPTERA : FORMICIDAE) OF FRUIT TREES IN MANIPUR, NORTH-EAST INDIA

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SUMMARY

Ten species of aphids under 6 genera, infesting 16 fruit trees growing within the altitude of 300 m to 2000 m in Manipur, have been dealt with. Nature of damage on the parts of the host plants, active periods of aphids and their associated 19 species of ants under 11 genera, have been furnished.

INTRODUCTION

Varieties of fruit trees grown in Manipur are infested by a number of insect groups, of which aphids form a major category of pests. In nature, the aphids have mutualistic association with ants. It has been found that ant association with aphid increases the aphid population to a certain extend and causes minor to severe damage to the fruit trees in Manipur.

Information on aphids infesting fruit trees in India is available in the works of Ghosh (1974), Raychaudhuri (1983), Agarwala and Raychaudhuri (1981), Basu and Banerjee (1958), Sharma *et al.* (1968). But none has undertaken on the aphids infesting the fruit trees in Manipur. Hence information on the aphid species infesting some fruit trees as well as with their aphidocolous ants in Manipur are presented here. Table 1 indicates that 10 species of aphids belonging to 6 genera with association of 19 species of ants under 11 genera are found infesting 15 fruit trees grown in this region, in different strata ranging from 300 m to 2000 m.

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TABLE 1. Host plant, aphid, host damage and active periods of aphids and aphidocolous ants in Manipur.

	Host plant Aphid species	Host damage and active periods of aphids	Aphidocolous ants
1.	*Artocarpus integrifolia*		
	Aphis gossypii Glover	Leaves and shoots (during July to August)	*Dolichoderus fuseus* Emery
	Greenidea (*G.*) *ficicola* Takahashi	Leaves and shoots (during January to March)	*Crematogaster flava* Forel
2.	*Citrus decumena* and *Citrus aurantium*		
	Toxoptera aurantii (B. d. F.)	Tender shoots, buds and leaves (during February to April)	*Camponotus* sp., *Dolichoderus fucus* Emery
3.	*Citrus lemonia*		
	Toxoptera citricidus (Kirkaldy)	Tender shoots, buds and leaves	*Camponotus* sp.
4.	*Emblica officinalis*		
	Aphis citricola (v. d. Goot)	Tender shoots and leaves (during September to November)	*Camponotus* sp.
5.	*Magnifera indica*		
	Toxoptera odinae (v. d. Goot)	Leaves, tender shoot and buds (during February to March)	*Tapinoma indicum* Forel
6.	*Musa paradisiaca*		
	Pentalonia nigronervosa Coquerel	Leaves and shoots (during December to March)	*Camponotus* sp., *Paratrechina* sp.
7.	*Ficus cunia*		
	Greenidea (*G.*) *ficicola* Takahashi	Leaves, and tender shoots (during January to March)	*Camponotus* sp.
8.	*Perkia* (*Roxbergii*) *javana*		
	Toxoptera odinae (v. d. Goot)	Leaves, tender shoots and buds (during November to February)	*Dolichoderus fucus* Emery
9.	*Prunus americana*		
	Myzus varians Davidson	Leaves and tender shoots (during February to May)	*Monomorium minutum* Mayr.
10.	*Prunus persica*		
	Hyalopterus pruni (Geoffroy)	Tender shoots and leaves (during February to May)	*Camponotus* sp., *Crematogaster flava* Forel

TABLE I. Continued

	Host plant aphid species	Host damage and active periods of aphids	Aphidocolous ants
11.	*Psidium guajava*		
	Greenidea formosana heeri Raychaudhuri, Ghosh, Banerjee and Ghosh	Tender shoot and leaves (during October to March)	*Dolichoderus affinis* Emery, *Dolichoderus fuseus* Emery, *Paratrechina longicornis* Latr.
12.	*Pyrus malus*		
	Aphis gossypii Glover	Leaves and shoot (during January to March)	*Dolichoderus affinis* Emery, *Paratrechina* sp.
13.	*Rhus similata*		
	Toxoptera odinae (v. d. Goot)	Leaves and tender shoot during (November to February).	*Anoplolepis longipes* (Jerdon), *Crematogaster ebenina* Forel., *Crematogaster rogenhoferi* Mayr., *Crematogaster travancorensis* Forel., *Dolichoderus fuseus* Emery, *Crematophldole smythusi* Forel., *Tapinoma indicum* Forel., *Technomyrmex albipes* Smith
14.	*Spondias magnifera*		
	Toxoptera odinae (v. d. Goot)	Leaves and tender shoot (during November to February)	*Technomyrmex albipes* Smith
15.	*Vanguirea spinosa*		
	Aphis citricola (v. d. Goot)	Tender shoots and leaves (during June to November)	*Anoplolepis longipes* (Jordon)

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KARYOMORPHOLOGY OF FOUR SPECIES OF APHIDS (HOMOPTERA : APHIDIDAE) FROM HIMACHAL PRADESH

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SUMMARY

A detailed karyomorphological investigation is presented alongwith the details of chromosome number, chromosome size, chromosomal abnormality and karyotypes of four aphid species viz., *Acyrthosiphon malvae* (Mosley) (2n=10), *Aphis kurosawai* Takahashi (2n=8), *Aphis ruborum longisetosus* Basu (2n=6) and *Liosomaphis atra* Hille Ris Lambers (2n=16+1). The cytological preparations were made from the early embryos, which were dissected out from the parthenogenetic viviparous females collected at different places from Himachal Pradesh. The chromosome size ranges from 2·17 μ to 7·57 μ in *A. malvae*, 2·62 μ to 7·12 μ in *A. kurosawai*, 5·96 μ to 8·12 μ in *A. ruborum longisetosus* and 2·70 μ to 5·44 μ in *L. atra*. The variation, polyploidy and evolutionary significance are discussed for these species in relation to known chromosome number in each genera for establishing the modal number.

INTRODUCTION

Now more than 685 species of aphids are known for their chromosomes world over (Kurl 1986) which constitute nearly 17% of the total (approx. 4000 spp.) taxonomically determined aphids. From Indian subcontinent more than 104 species have so far been investigated cytologically (Kurl 1986 ; Chauhan 1987) describing their chromosome numbers only. The Indian aphid species are yet to be investigated for their detailed karyomorphology, although few references are available for their chromosomal studies (Kurl 1980 ; Kulkarni and Kacker 1980 ; Khuda-Bukhsh 1980 ; Pal and Khuda-Bukhsh 1982 ; Khuda-Bukhsh and Pal 1983 ; Kurl and Chauhan 1986 a, b).

In continuation to our chromosomal studies on aphids of Himachal Pradesh (Kurl and Chauhan 1986 a, b, c, d, 1987) four more species are being reported here for their karyomophology.

MATERIALS AND METHODS

Parthenogenetic viviparous aphids of the species were collected from different host plants and from different localities of Himachal Pradesh (Table 1). Young embryos were dissected out from the live aphids and were fixed in 3 : 1 methanol acetic acid and were further subjected to cytological preparations by air dry Giemsa staining method (Kurl and Narang 1978). Atleast 25 well spread metaphase complements were studies for the details of chromosome in ea ch species.

TABLE I. Aphid species, their host plant, locality, dat e of collection and chromosome number.

Aphid species	Chromosome number (2n)	Host plant (locality)	Date of collection
Acyrthosiphon malvae (Mosley)	10	*Rubus elliptious* (Barog)	10·XI·86
Aphis kurosawai Takahashi	8	*Buddeleja* sp. (Solan)	11·XI·86
Aphis ruborum longisetosus Basu	6	*Rubus illipticus* (Solan)	11·XI·86
Liosomaphis atra H. R. L.	17	*Berberis* sp. (Barog)	10·XI·86

RESULTS AND DISCUSSION

1. Acyrthosiphon malvae (Mosley) :

The cytology of this aphid was hitherto unknown. For the present study the material was collected from Barog (Table 1). Only one sample was available for study.

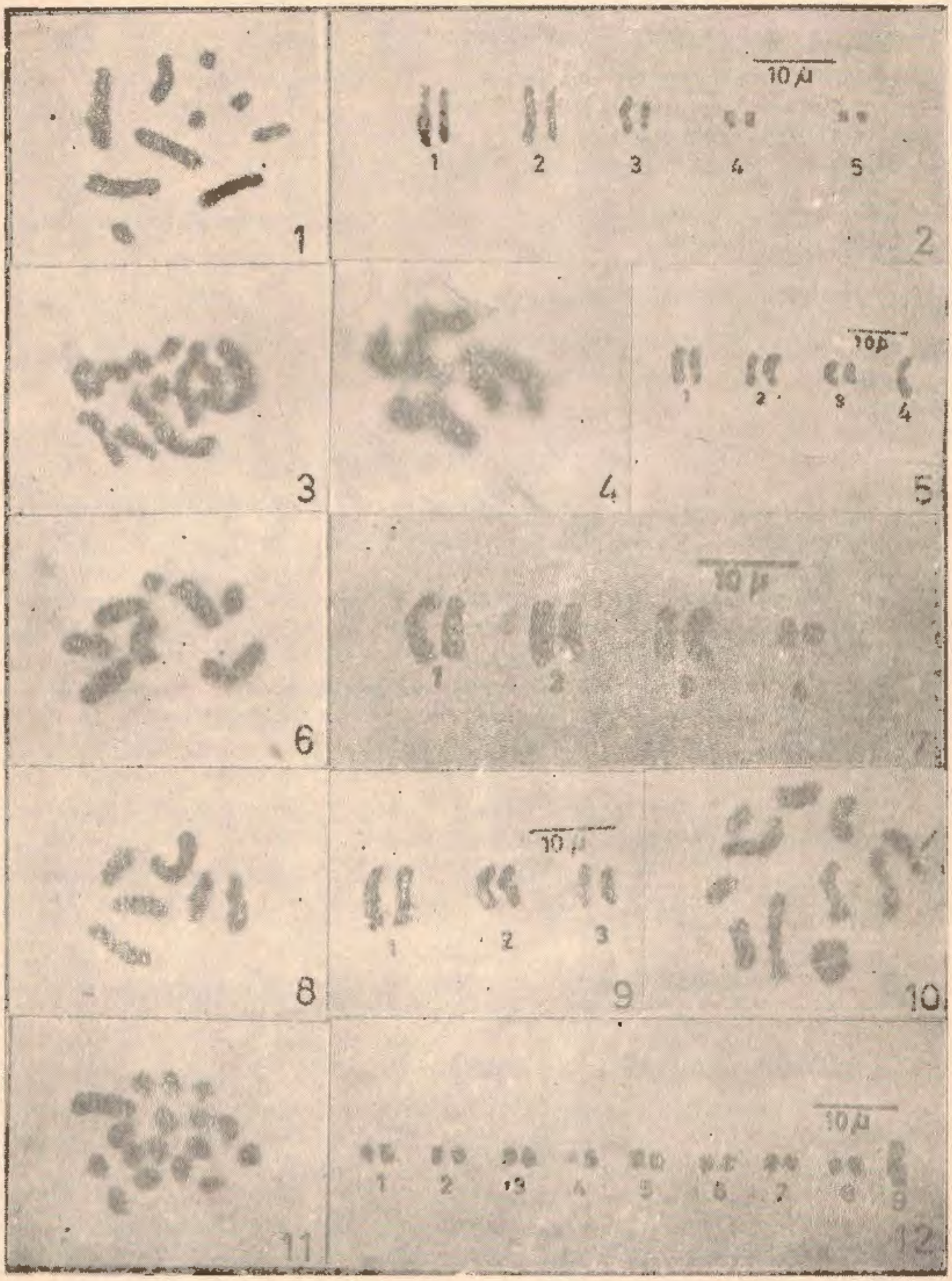
The chromosome number was ascertained as 2n=10 (Fig. 1) after counting in atleast 50 prometaphase (Fig. 3) and metaphase complements. The metrical data is given in Table 2. The karyotype (Fig. 2) was prepared, which depicts the presence of two long sized pairs, one medium sized pair and two short, dot like pairs of chromosomes in each complement.

The present finding is the first report for the cytology of this aphid.

2. Aphis kurosawai Takahashi :

Earlier it was Blackman (1986) who studied its chromosomes and reported 2n=8 from Japan. We collected the material of this species from Solan, Himachal Pradesh. Only one sample (Table 1) was available for cytological investigations.

The diploid chromosome number was established after counting 18 prometaphase and metaphase complements, and was found to be 8 (Fig. 6) At metaphase the chromosomes were very much condensed and rod shaped while at prometaphase they were quite long with their clear morphology. The karyotype (Fig. 7) was prepared. From karyotype it is clear that there are one long pair, two medium sized pairs and one short pair of chromosomes.



Figs. 1–12. Chromosomes and their karyotypes of aphids :
Acyrthosiphon malvae—2n=10 chromosomes (Figs. 1 and 3), karyotype (Fig. 2) ; *Aphis kurosawai*—2n=7 chromosomes (Fig. 4), abnormal karyotype (Fig. 5), 2n=8 chromosomes (Fig. 6), normal karyotype (Fig. 7) ; *Aphis ruborum longisetosus*—2n=6 chromosomes (Fig. 8), karyotype (Fig. 9), polyplo id compliment (4n=12) (Fig. 10), satellite marked by arrow; *Liosomaphis atra*—2n=17 chromosomes (Fig. 11), karyotype (Fig. 12).

In some of the complements the aneuploid number 2n=7 (Fig. 4) was also observed but the frequency of these complements was very low. The karyotype (Fig. 5) for this abnormal complement was also prepared which shows that there are 3 pairs of chromosomes of 3 different sizes, *i.e.* long, medium and small, besides one longest unpaired chromosome (Fig. 5) which may be regarded as sex chromosome. The metrical data are provided in Table 2.

The present finding is the first from India and confirms the earlier findings of Blackman (1986).

3. **Aphis ruborum longisetosus** A. N. Basu :

It was Khuda-Bukhsh (1979) who studied the chromosomes of this species and reported 2n=8 chromosomes for this species.

The material for the present investigation was collected from Solan (Table 1) infesting the host plant, *Rubus ellipticus* (Family-Rosaceae).

Our observations from the slides prepared from this lone sample revealed that this species was having 2n=6 chromosomes (Fig. 8). To ascertain this diploid number of chromosomes we studied as many as 30 prometaphase and metaphase complements. However, some of the complements had aneuploid numbers (2n=5). At prometaphase the chromosomes appeared to be less condensed and took light stain, but their morphology was clear. The karyotype (Fig. 9) was prepared which depicts that there are one long pair and the remaining two pairs are approximately of the same lengths and are shorter than the first pair.

Polyploidy was observed in the preparations with high frequency. In prometaphase polyploid complements (4n=12) (Fig. 10) the chromosomes appeared to be in homologous pairing. In one of the chromosome (Fig. 10) the satellite was quite evident which is marked by arrow. The metrical data is provided in Table 2.

Our findings for the diploid chromosome number (2n=6) is in contradiction with that of the earlier report by Khuda-Bukhsh (1979).

4. **Liosomaphis atra** Hille Ris Lambers :

This species is known to have its distribution in Australia, England, Europe, India, Japan, Newzealand and North America. Only two species of the genus, *Liosomaphis* are known for their chromosomes (Kurl 1986).

Our material for the present investigations was collected from Barog, Himachal Pradesh (Table 1). Only one sample was available for cytological investigations.

TABLE 2. Metrical data including mean actual lengths (I) and mean relative percentage lengths (II) of the chromosomes of four aphid species.

Aphid species		Chromosome number																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Acyrthosiphon malvae	I	7·57 ± 0·26	7·57 ± 0·26	7·57 ± 0·26	7·57 ± 0·26	4·40 ± 0·35	4·40 ± 0·35	2·82 ± 0·14	2·82 ± 0·14	2·17 ± 0·16	2·17 ± 0·16							
	II	15·42 ± 0·53	15·42 ± 0·53	15·42 ± 0·53	15·42 ± 0·53	8·97 ± 0·71	8·97 ± 0·71	5·74 ± 0·29	5·74 ± 0·29	4·42 ± 0·33	4·42 ± 0·33							
Aphis kurosawai	I	7·12 ± 0·15	7·12 ± 0·15	6·15 ± 0·29	6·15 ± 0·29	5·68 ± 0·23	5·68 ± 0·23	2·62 ± 0·41	2·62 ± 0·41									
	II	16·49 ± 0·35	16·49 ± 0·35	14·25 ± 0·67	14·25 ± 0·67	13·18 ± 0·53	13·18 ± 0·53	6·07 ± 0·21	6·07 ± 0·21									
Aphis ruborum longisetosus	I	8·12 ± 0·23	8·12 ± 0·23	6·68 ± 0·38	6·68 ± 0·38	5·96 ± 0·24	5·96 ± 0·24											
	II	19·55 ± 0·55	19·55 ± 0·55	16·08 ± 0·92	16·08 ± 0·92	14·35 ± 0·58	14·35 ± 0·58											
Liosomaphis atra	I	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	2·70 ± 0·15	5·44 ± 0·20
	II	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	5·54 ± 0·30	11·18 ± 0·41

Twenty two metaphase complements were studied and counted to ascertain the chromosome number in this species which was found to be 2n=17. Almost all the cells studied, possessed this odd number of chromosomes (Fig. 11) except one or two complements where chromosomes number 2n=18 was seen. Their frequency was so low, thus this number needs further investigations. At metaphase (Fig. 11) the chromosomes were quite distinct and took dark stain with very clear morphology. While preparing the karyotype assuming the chromosomes of equal lengths to be homologous, it is found that only eight pairs may be treated as homologous, leaving a single unpaired long sized chromosome number 9 (Fig. 12) in each karyotype. More investigations and explanations are needed to describe this odd number of chromosomes in a complement. The measurements of all 17 chromosomes are given in Table 2. We have also seen the polyploid complements where the two pairs of long sized chromosomes are clearly visible. The present report is the first for the cytology of this species.

The genus *Acyrthosiphon* is known cytologically by 8 species (Kurl 1986), out of which 5 species have 2n=10 chromosomes while only 3 species have 6, 8 and 12 chromosomes. It appears that modal number for this genus is 10. More than 58 species of the genus *Aphis* have so far been investigated cytologically. Majority of them possessed 2n=8 with a little variation. It has already been established that modal number is 8 for this genus. The genus *Liosomaphis* is known cytologically by 3 species including the present one and all the 3 possess 2n=18 and thus this can be accepted as its modal number. However, in the present studies we observed 2n=17 for the species *L. atra* which may be regarded, a report from male cells.

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