PRANIKEE

Journal of
ZOOLOGICAL SOCIETY OF ORISSA

Volume IV 1983

ZOOLOGICAL SOCIETY OF ORISSA

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PRANIKEE

THE APHIDS

(RECENT TRENDS IN APHIDOLOGICAL STUDIES)

Proceedings of symposium held at
Utkal University, Bhubaneswar

Edited by

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THE ZOOLOGICAL SOCIETY OF ORISSA

POST-GRADUATE DEPARTMENT OF ZOOLOGY

UTKAL UNIVERSITY

BHUBANESWAR-751 004

INDIA

This volume of PRANIKEE contains papers presented during the symposium on "RECENT TRENDS IN APHIDOLOGICAL STUDIES" held at Bhubaneswar from June 9 to 12, 1979.

This is the first comprehensive compilation of work on aphids contributed by people from all over India. It is hoped that this will be a guide and reference book both for contemporary and future aphidologists. Dr. B. K. Behura, the convener of the symposium has kindly written the introduction to this volume.

The financial aid for this publication has been provided by the Director of Public Instruction, Orissa; State Youth Welfare Board; Utkal University; National Institute of Science and Zoological Society of Orissa

P. Mohanty-Hejmadi
Editor

In the four-day symposium held on "Recent trends in aphidological studies" held at Bhubaneswar from June 9 to 12, 1979, over seventy zoologists, botanists, virologists and agricultural scientists drawn from different parts of India participated and a total number of one hundred papers spread over ten sections were presented and discussed. The work of editing them was entrusted to me. Dr. J. M. Satapathy, Department of Entomolgy, Orissa University of Agriculture & Technology, Bhubaneswar, Dr. A. K. Ghosh, Zoological Survey of India, Calcutta; Dr. M. R. Ghosh, Department of Agricultural Entomology, Bidhanchandra Krishi Viswavidyalaya, Kalyani; Prof. G. K. Manna, Department of Zoology, Kalyani University, Kalyani and Prof. J. S. Datta Munshi, Department of Zoology, Bhagalpur University, Bhagalpur rendered yeoman assistance in this regard. The edited papers totalling 60 have been finally grouped under six sections including a section for Short Communications.

For organizing the symposium financial assistance was received from the University Grants Commission, New Delhi and the Utkal University, Bhubaneswar.

For the publication of the papers presented in the symposium, financial assistance has been received from the National Institute of Sciences, New Delhi and the Zoological Society of Orissa.

Grateful thanks are due to the above.

B. K. BEHURA

Convener's Report

Respected Vice-Chancellor, Professor Samantarai, Professor Raichaudhuri, delegates, ladies and gentlemen,

The most important issue before the world, is perhaps, how to get rid of the grinding poverty which afflicts 1,000 million people in the poor countries in the world, of which India is one. The spirit of scientific research is the search for truth and discovery of Nature and betterment of human conditions.

The Government of India's science policy is based on a resolution adopted in the Parliament in March, 1958. This was framed by Late Pandit Jawaharlal Nehru and Late Dr. Homi Bhaba, the great atomic energy scientist of the country. The aims and objects include securing for people the benefits from the acquisition of scientific knowledge and its application, encouragement of individual initiative for acquisition and dissemination of knowledge, training of science and technical personnel for agriculture, industry and defence.

Prime Ministers of India have one after the other repeatedly advised the scientists of the country to carry the results of their researches to the masses.

With encouragement from our Prime Ministers, 130 National laboratories, 200 other laboratories and research institutions have been set up. The expenditure on scientific research in our country increased from Rs. 4.7 crore in 1950-51 to about Rs. 400 crore in 1976-77. Agricultural research has been carried out for the past many years by the Indian Council of Agricultural Research with the help of its 24 institutions and 21 agricultural universities.

Aphids, green bugs or plant lice are small insects, the different aspects of which are the area of investigation by the pure-scientists and the applied scientists to combat with them from spreading the deadly plant viruses which devastate the crops in addition to sucking out the juice of healthy crops. This symposium on aphids has brought applied scientists and pure scientists together which we hope will provide ample opportunities to discuss problens which are being created by the tiny monsters.

On this occasion, we will be failing in our duties if we forget to remember the first Indian aphidologist Shri Bashambar Das who studied the Aphididae of Lahore for the degree of D. Sc. and who succummed to an untimely death in 1913 while attending to one of his students suffering from cholera.

The idea of having a separate symposium of aphidologists, was hatched, years back in the Zoology Department of the Calcutta University by Professor Dr. D. N. Raychaudhuri and me who with his school has done pioneering taxonomic work on the aphids of North-Eastern India. The idea gained further impetus, when I choose, at the instance of Professor G. K. Manna of Kalyani University to speak on the "Biology of Aphids" as my presidential address to the 65th Indian Science Congress in January, 1978 at Ahmedabad, in the Section of Zoology, Entomology and Fisheries. This year, the University Grants Commission came forward with a grant-in-aid to hold the symposium. The Utkal University has also contributed generously towards the same. The State Department of Agriculture with Dr. G. C. Sengupta, basically an aphidologist, has rendered us help without which, we could not have organized this symposium with our extremely limited resources in an University Department. To crown all, Major G. P. Mohanty, Principal, B. J. B. College Bhubaneswar gave the final go, by solving our problems of accommodation and boarding arrangements for the delegates. To all of them and to many others who have rendered us service our grateful thanks are due. The members of the staff, and students of my Department have worked tirelessly to make it a success.

We thank you all for your kind cooperation and collaboration. We hope our symposium on aphids will bear fruitful results. Publilius Syrus rightly said, "It is no profit to have learned well, if you neglect to do well".

B. K. Behura
PROFESSOR OF ZOOLOGY
UTKAL UNIVERSITY
BHUBANESWAR

June 9, 1979

THE APHIDS

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I. ECOLOGY

AERIAL ACTIVITY OF SOME APHIDS IN KALIMPONG, WEST BENGAL

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ABSTRACT

There are two peaks in the alate activity of aphids at Kalimpong, Darjeeling, West Bengal, viz., March-April and November-early January.

INTRODUCTION

Dispersal of aphids is accomplished by alate adults. The apterous females that are most often met with on plants are not important with regard to the spread of infestation as they are very sluggish and move very little from plant to plant by crawling. Even though the alates are responsible for dispersal, active flight by them is limited to the take off from the plant and alighting on the plants when they are taken to the vicinity of the hostplant or any substrate that may appear attractive to them. Therefore, long distance dispersal is a passive phenomenon of drifting in wind current. Sampling of aerial populations gives an indication of the intensity of dispersal of aphids. Among many methods, sampling by yellow-pan-water-trap is one. This trap, however, samples aerial population which positively responds to the yellow colour and further, such sampling is from uncontrolled volume of air (Taylor and Palmer, 1973). With a view to gather information on the periodicity of dispersal of a few aphids/pests of some economic plants, viz., *Aphis* spp., *Brachycaudus helichrysi* (Kalt.), *Lipaphis erysimi* (Kalt.), *Myzus persicae* (Sulz.) and *Toxoptera aurantii* (B.d.F.) trapping was done for two consecutive years at Kalimpong (*c* 1,500 m) during 1970 and 1971 and the results are presented in the following.

MATERIAL AND METHODS

Rectangular yellow-pan-water traps 50 cm × 35 cm with the upper part of the side walls gradually slanting to the bottom to make the basal length and breadth 46cm and 31cm respectively at a depth of 7.5cm from the top were used for the study. They were painted chrome yellow and filled ¾th with clean water as media of catching aphids. One such trap was operated at crop level at about 30 cm from the ground and another at 2 m above ground in the vicinity of the trap at about ground level. These traps were operated daily for two years, 1970 and 1971. Collection of alate aphids was done daily just before dusk in 70% alcohol and the different species were sorted out under the microscope after making microscopic preparations of the aphids and the number of each species trapped was counted. Such records were maintained for the two traps separately. When a large number of aphids was collected in a day preliminary sorting of the species was done under binocular microscope which was verified with the help of microscope in doubtful cases. The traps were replaced with fresh ones when the colour of the traps was found to have faded by weathering in the field and water of the traps was changed daily at the time of collection to remove other insects and foreign materials accumulated. Meteorological data were also recorded daily.

RESULTS AND DISCUSSION

The aphids dealt with here respond positively to the yellow colour of the traps. The genus *Aphis* is represented by as many as 8 different species on plants in the locality of the present study, but *Aphis craccivora* Koch., and *A. gossypii* Glover have been found to be the dominant ones and these occur throughout the year. Further, their population trend in the field has been found to be more or less similar and, therefore, discussion on alate activities of *Aphis* spp. has been restricted to *A. craccivora* and *A. gossypii* together. The results presented here denote total catch of different species during the fortnight of a month and the meteorological data is the average of each of the meteorological factors for the corresponding periods (Figs. 1 and 2).

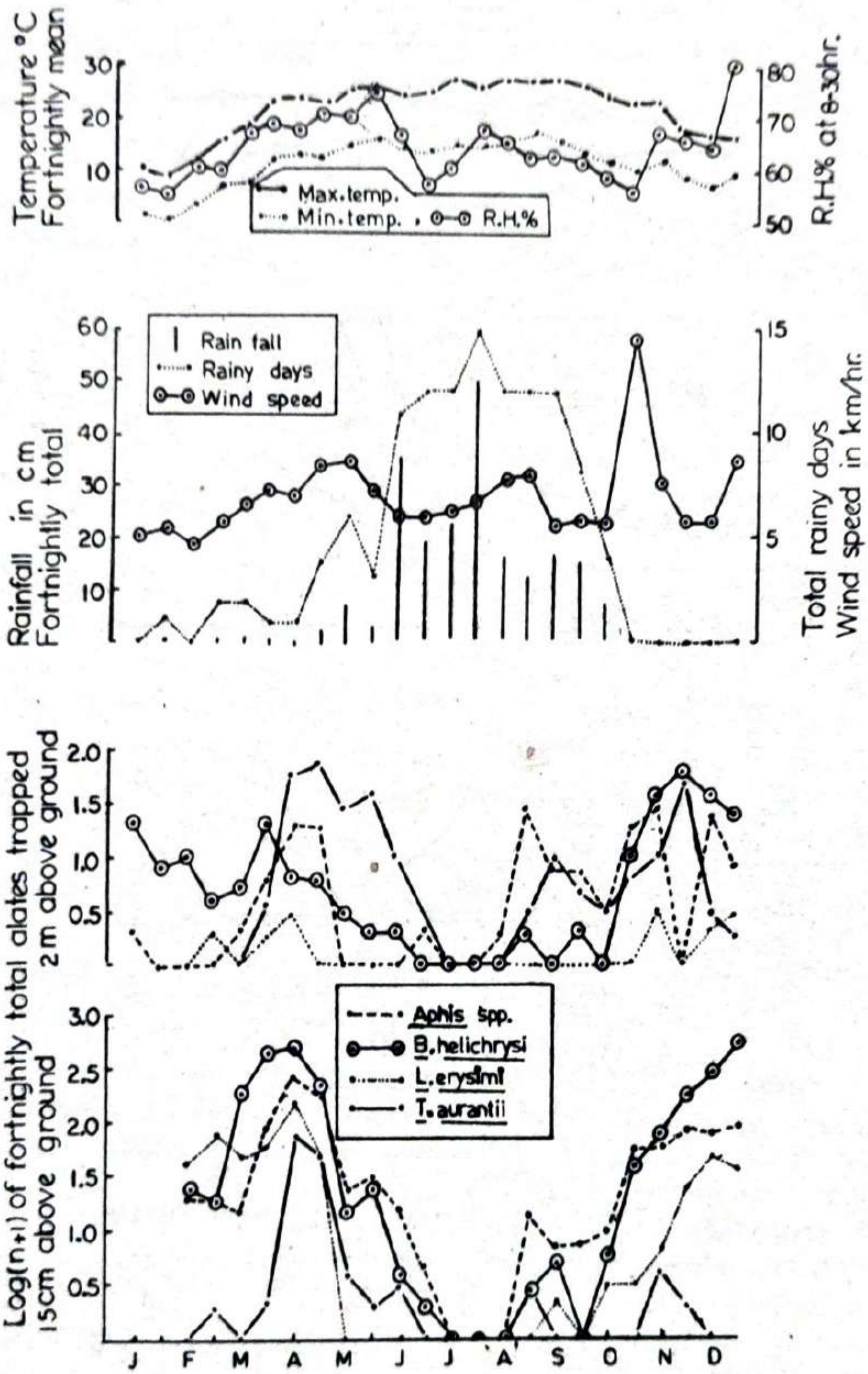

Fig. 1 Air borne alate activity of some aphids at Kalimpong in 1970.

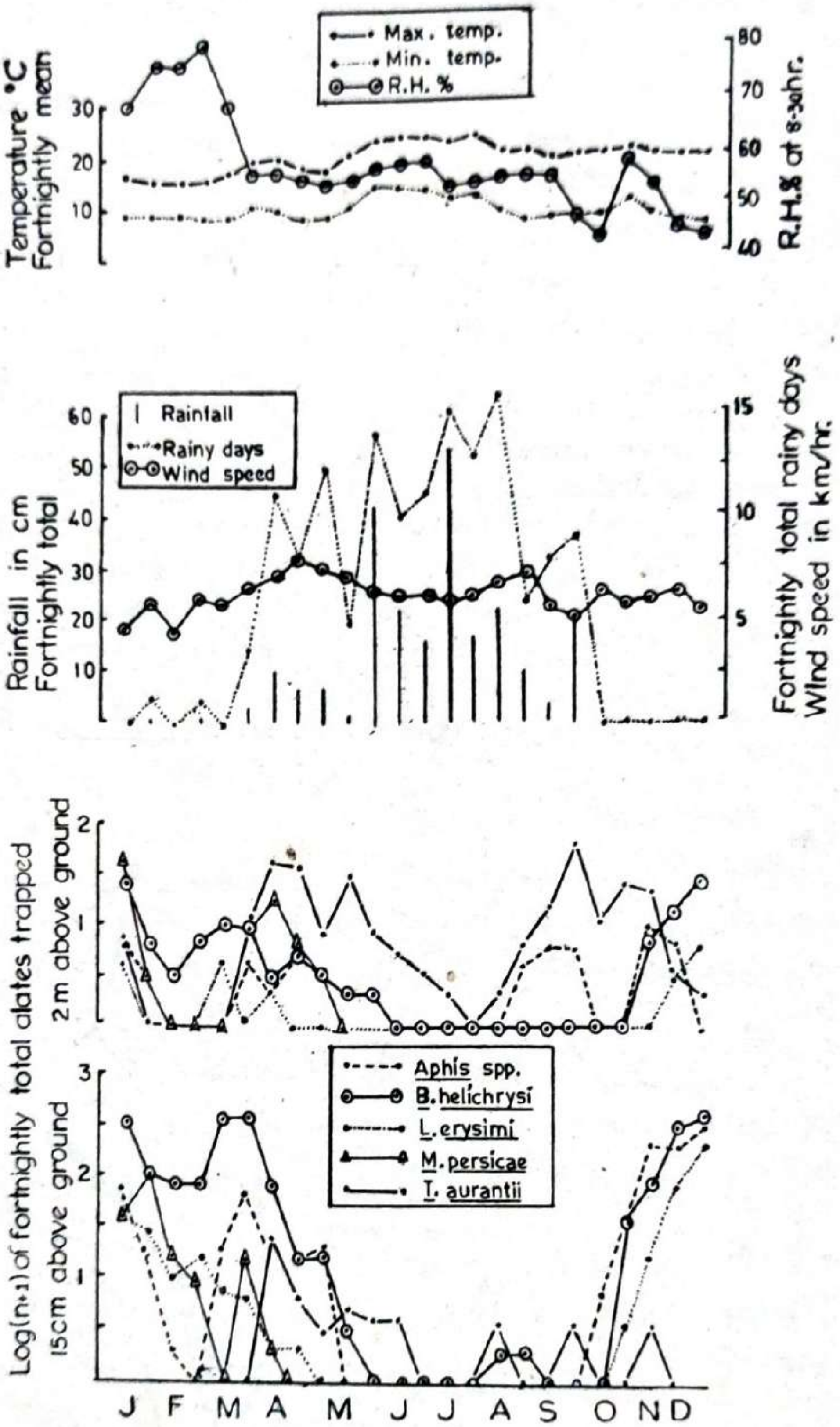

Fig. 2 Air borne alate activity of some aphids at Kalimpong in 1971

(a) Trapping near ground level :

The number of alates trapped during different periods of a year varies remarkably. None-the-less a trend in the fluctuation of trapped alates is discernible. Usually, the number of alates recorded indicates well-defined peaks one during spring (March-April) and another during winter (December-January). Further, a definite period of much diminished activity of alates during rainy season (June-August) is noticeable as none or a very small number of alates could be recorded in the traps.

The total number of *Aphis* spp. trapped during the two years of study show very little variation. By *Aphis* spp. are meant *Aphis craccivora* and *A. gossypii* together in view of dominance of these two species in the field and also because of the parallelism in their behavior. In spite of more or less similar annual catch of these aphids in the traps there occurred some shifting in the peak period in the two years. In 1970 higher catch was recorded during the first fortnight of April and December which in 1971 occurred during second fortnight of March and December. Besides, intensity of alate activity also varied in these two years. This is apparent from the fact that in 1970 the number of alates trapped in April was much higher (285) than in December (91) while in 1971 the number of alates trapped in March was much less (71) than that of December (334).

Unlike *Aphis* spp. annual catch of *Brachycaudus helichrysi* (Kalt.) is appreciably different. In 1970, the peak of alate activity was noticed during the first fortnight of April and December while in 1971 the peaks shifted to the second fortnight of March and December. It may be pointed out here that no appreciable difference in the number of alates trapped could be observed in the winter and spring peaks.

Aerial activity of the alates of *Lipaphis erysimi* (Kalt.) and *Myzus persicae* (Sulz.) has been found to be very restricted only to a part of the year since these species are available only for a short period, from winter to spring. Collection of the two species of aphids in the traps during the two seasons is in conformity with their occurrence in the field. Species-wise consideration of alate activity reveals that the total annual catch of *L. erysimi* varied very little during the two years of observation. However, in 1970 it shows one peak during the first fortnight of April and the other during the first fortnight of December while in 1971 the peaks are observed during the second fortnight of February and December. With regard to *M. persicae* the data of 1971 are considered since 1970 catch was extremely meagre. However, in 1971 one peak was observed during the first fortnight of January and the other during the first fortnight of April. Thus it appears that though these two species have similar seasonal activity on their host plants, the aerial activity of the alates vary greatly.

The aerial activity of alates of *Toxoptera aurantii* shows substantial departure from that mentioned above. This species, like *Aphis* spp. and *B. helichrysi*, occurs persistently on its host plants in the region of the present study. In 1970, it first appeared in the traps during the second fortnight of March while in 1971 it was caught during the first fortnight of April. The peak period of alate activity was in the first fortnight of April in both the years. During 1970 no alate could be trapped from the second fortnight of June till the end of the year except for a meagre catch during the second fortnight of August. During 1971 none were trapped in July and December but intermittant and small catches were made during August to November.

(b) Trapping at 2 m above ground :

The alate activity as recorded in this trap is more or less the same as that recorded in the trap placed near the ground level. However, some shifting in the peak periods of activity and difference in the number of alates trapped for some species are noticed.

Total number of alates of *Aphis* spp. trapped during 1970 at 2 m above ground was appreciably higher than that of 1971 but, in the trap placed near the ground level no appreciable difference in the total number in the two successive years could be observed. During 1970 the peak activity was during the first fortnight of April as was also revealed from the data in the trap placed near the ground level But the winter peak was in the first fortnight of November i. e., a month ahead of that in the trap placed near the ground level. The record of trapping in 1971 was very low and no well-defined periodicity could be discerned.

For *B. helichrysi* also the total annual catch in this trap was much less than in the trap placed near the ground level. There was, however, not much difference in total catch when the data of 1970 and 1971 are compared. The activity of alates during spring was not so pronounced as in the trap placed near the ground level though the number of alates recorded in this trap (at 2 m above ground) was rather high during second fortnight of March in both the years. In 1970 higher catch of alates of this species in the trap placed at ground level was during first fortnight of April. The winter peak in this trap (at 2 m above ground) was found to stretch from second fortnight of December to first fortnight of January in both the years and was less pronounced tban spring peak. In this case also the peak period was slightly different from that in the trap placed near ground level. In the rainy season no data could be recorded.

In case of *L. erysimi* and *M. persicae* period of alate activity was more or less the same when trap-catch placed at 2m above is compared with that placed near ground level. The number of alates trapped during both the years was very few and it was difficult to make out any trend.

The pattern of fortnightly total catch was substantially different in *Toxoptera aurantii* than that for species disscussed earlier. The total number of alates recorded in this trap during a year was higher than that placed near the ground level. But comparison of the annual catches in this trap did not reveal any appreciable difference. Spring peak, however, in both the years for this trap was pronounced. In this respect there was no deviation in respect of traps placed near the ground level. There was no record of alates during January to first fortnight of March and then again from second fortnight of June till first fortnight of August during 1970. In 1971 alate activity was nil during second fortnight of January to first fortnight of March and first fortnight of August. This is indicative of the fact that winter condition does not favour alate activity of this aphid and that rains do not deter activity though only a few could be recorded during this season.

GENERAL REMARKS

The aphids, *Aphis* spp., *B. helichrysi* and *T. aurantii* persistently occur in the area of the present study while *L. erysimi* and *M. persicae* are seasonal. This attribute of these species in addition to the influence of weather factors determines to a large extent the activity of the alates. *Aphis* spp. and *B. helichrysi* were recorded almost throughout the year in the traps excepting for a short period of their absence during July—August when a large amount of rainfall was experienced in the area. *T. aurntii* did not exhibit any such biological trait. The absence of alates of *L. erysimi* and *M. persicae* in the traps for a major period of the year can possibly be attributed to their absence on the plants during the corresponding period. However, all these species exhibit more or less well-defined period of intense alate activity. There occur two peaks for such activity, once during spring (March—April) and another during winter (December—January). The conditions favourable for heavy population build up just prior to peak alate activity leads to the production of alates in large numbers for dispersal. Such dispersal of the alates may also be caused if the host condition and weather conditions become unfavourable. The weather conditions during the peak alate activity should be such that they may become easily air borne.

All the species excepting *T. aurantii* were recorded in much higher number in the trap placed near the ground level than in the trap placed 2 m above ground. The type of plants usually utilised as hosts may be looked upon as a factor for this kind of data. *T. aurantii* infest succulent twigs of woody trees while the other species infests herbaceous plants. It is, therefore, likely that *T. aurantii* is active at higher stratum of air to reach the desired sites of infestation while alates of other species are more active on the lower stratum of air to acquire newer host plants.

Calculation on the simple correlation of alate activity of different species with some of the weather factors prevalent during the corresponding period (Table 1) reveal some interesting results. It is generally noticed that the density of air-borne aphids as depicted by the number of alates trapped is significantly negatively correlated with temperature excepting *T. aurantii* where positive correlation is found. The alate activity for most of the species is significantly positively correlated with RH% and negatively so with rainfall. Such significant correlations were usually not obtained by Roy (1976) who did not find any correlation with weather factors for *L. erysimi* in the plains of West Bengal, and Kareem and Basheer (1965) found correlation for aphids trapped with only percentage of relative humidity in South India. Johnson (1969) opined that attempts to establish correlation with abiotic factors alone for aphid flight activity is difficult as the flight activity is intimately related with factors like host condition and population density. It may, therefore, appear that the degree of correlation with weather factors for alate activity in this region is a special situation. The more salubrious weather condition obtained in this region is probably the reason for such situation.

TABLE 1

Correlation coefficient (r) of aphids trapped with different weather factors.

	Placement of trap	1970 Temp. °C Max.	1970 Temp. °C Min.	1970 RH%	1970 Rainfall	1971 Temp. °C Max.	1971 Temp. °C Min.	1971 RH%	1971 Rainfall
B. helichrysi	Ground level	− 0.33*	+ 0.059	+ 0.55*	− 0.48*	− 0.50*	− 0.41*	+ 0.07	− 0.45*
	2 m above	− 0.37*	− 0.32*	+ 0.38*	− 0.46*	− 0.39*	− 0.39*	+ 0.08	− 0.39*
***Aphis* spp.**	Ground level	− 0.31*	+ 0.02	+ 0.41*	− 0.44*	− 0.17	− 0.46*	− 0.25	− 0.34*
M. Persicae	Ground level	− 0.42*	− 0.35*	+ 0.18	− 0.47*				
T. aurantii	Ground level	+ 0.06	− 0.02	+ 0.23	− 0.20				
	2 m above	+ 0.24	+ 0.26	+ 0.43*	− 0.19				

* significant at 5% level

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ALATE ACTIVITY OF APHIDS DURING SUMMER MONTHS IN SOUTHERN KERALA

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ABSTRACT

From the present investigation it emerges that: (1) The maximum activity of alates during the period of study was during the first 2 weeks of March, both in the forenoon and in the afternoon; (2) Higher catch was obtained ln the forenoon (88%) compared to the afternoon catch (12%); (3) Take off of alates occurred between 9 a. m. and 10 a. m.; (4) The trapping of alates gradually increased from morning and the maximum number was trapped between 10 a. m. and 12 noon. Then, gradually, the number decreased as the day approached dusk; (5) Windspeed and temperature were found to have a negative influence on the trapping; (6) The aphids under observation were found to be mature females bearing embryos at the time of the migratory flight.

INTRODUCTION

Dispersal is one of the most important events in the ecology of animals. In aphids, the major intrinsic mechanism of dispersal is by the production of alates and their migration. Therefore, aerial movement of aphids is of considerable interest as part of general study of aphid ecology or of pest control programmes. In India, Ghosh and Raychaudhuri (1979) studied the settling behaviour of air borne aphids under field conditions in Kalimpong (ca. 2200 m) in West Bengal and found that there was a distinct pattern of settling of aphids in the course of the day and that this pattern showed seasonal changes. Since there is considerable regional difference in the climate and vegetation in India, a study of the aerial activity of aphids was undertaken in Kerala.

METHODS OF STUDY

A cylinder about 30 cm × 12 cm, mounted on a bamboo pole (1.2 m high) was used (Taylor and Palmer, 1973). The cylinder was covered with a lemon yellow paper and a cellophane cover which was greased. It was operated from the 4th week of February to the 1st week of May 1979. Four similar traps were set up simultaneously in the open ground.

Almost everyday, two sets of observations were made, one in the forenoon and the other in the afternoon. At the end of the week, the greased cellophane was replaced by a fresh one. A survey of abundance of the hosts of ***A. fabae solanella*** and ***A. gossypii*** in the campus was made. The time of take off of alates from ***Eupatorium*** was also noted.

OBSERVATION AND DISCUSSION

The catches of alate aphids during summer months on a weekly basis are represented in Figure 1 separately for the forenoon and afternoon together with the meteorological data for the above period, as weekly means for each factor, except rainfall, for which total precipitation of the week has been given.

The data indicated a general trend of increase of the mean temperature during the period of study. Another climatic factor that showed an almost consistent change was the windspeed, which in general showed an increase with increase in temperature. Both rainfall and relative humidity showed considerble variation from week to week.

It is reasonable to presume that the catch of alates on the trap is a measure of the population of alate individuals present in the air. The number of alates in the air would however be dependent on the number of alates produced, number of alates that take off, time of take off and the number of alates attracted towards the host plants and wanting to settle.

It has been observed that the weekly catch of aphids was low in the 4th week of February but reached the highest during the 1st week of March. It was lower in the second week of March compared to the previous week; thereafter a sharp decline in the catch was noted. No aphid was caught in the trap in the fourth week of April. This could only mean that alate production was high during the first three weeks of March and declined sharply afterwards, remaining very low during the rest of the period of study.

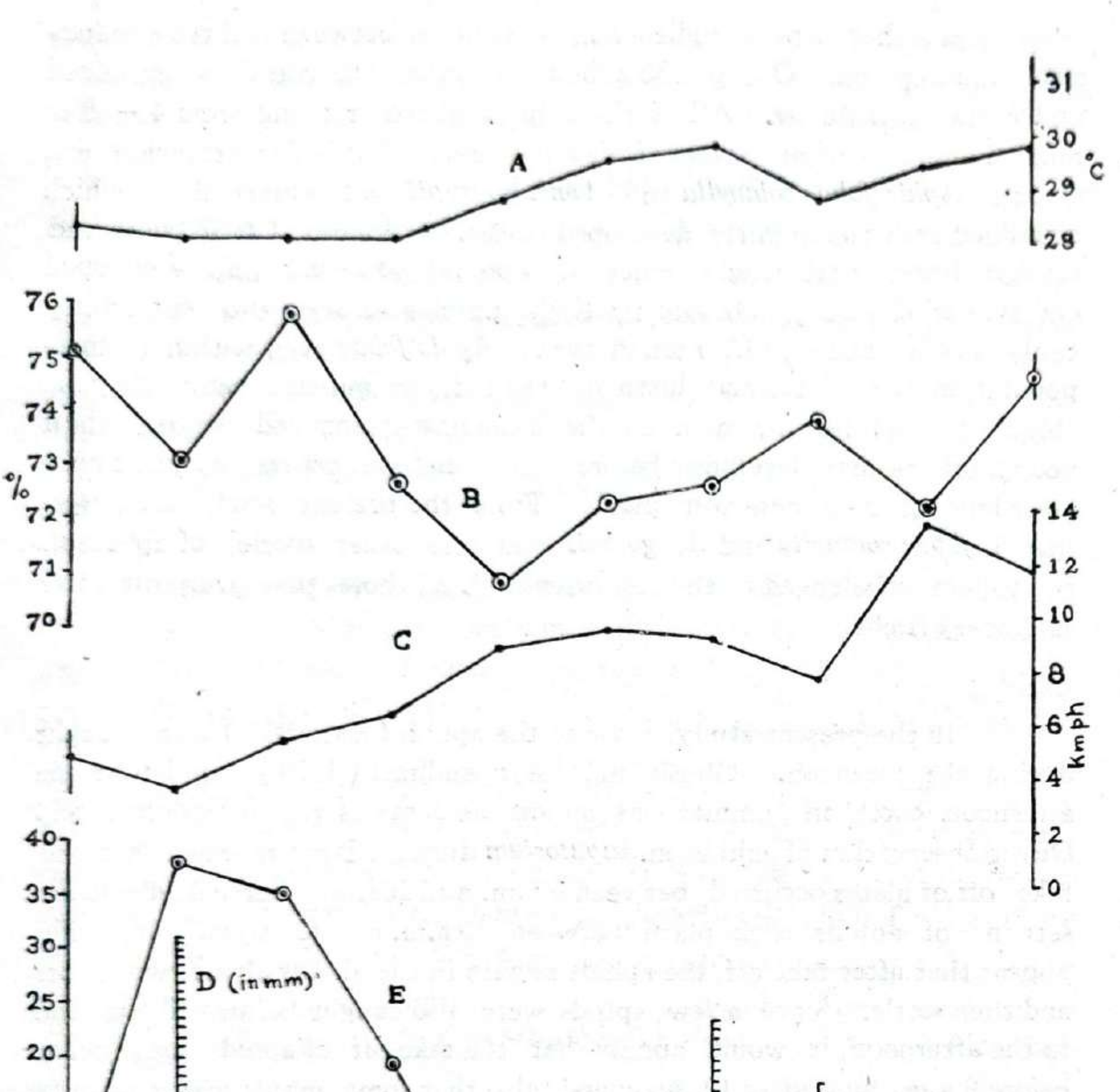

Fig. 1 (Legend on page 16)

Another aspect studied was the relation between embryo production and migration. Out of 130 aphids collected, 112 could be examined under the microscope. All of them had embryos ranging from 4 – 8 in number and in various stages of development. Particular attention was given to *Aphis fabae solanella* and *Aphis gossypii* individuals, all of which contained embryos in fairly developed stages. Johnson (1957) observed in Aphidinae, that newly emerged aphids possessed well developed embryos which are born before the flight muscles autolyse and the ability to fly is lost. Shaw (1970) found that in *Aphis fabae* even within a single population few alates may histolyse their flight muscles before they are able to fly and hence remain on the same host plant and deposit their young; others may larviposit before flight and still others larviposit only after landing on a new host plant. From the present study it emerges that *A. fabae solanella* and *A. gosspii* and also other species of aphids in the collection belonged to the last category i. e., those that larviposit after migratory flight.

In the present study, most of the aphids (upto 88%) were caught during the forenoon. Ghosh and Raychaudhuri (1979) found that the afternoon catch in summer was almost as large as the forenoon catch. Direct observation of aphids on *Eupatorium* during March revealed that the take off of alates occurred between 9 a.m. and 10a.m. Further, maximum settling of aphids took place between 10 a.m. and 12 noon. It would appear that after take off, the aphids remain in the air for about two hours and then settle. Since a few aphids were also caught before 10 a.m. and in the afternoon, it would appear that the take off of aphids may occur before 9 a.m. and after 12 noon and also that some aphids may remain in the air for more than 2 hours. There was no trapping before 8 a.m. and after 6 p.m. Earlier studies in aphids showed that though they can remain in the air for about 14 hours after take off (Cackbain, 1961) in nature, the more usual duration is about 3 hours or less (Johnson, 1957). Ghosh and Raychaudhuri (1979) could observe two peaks of alate activity in March and April— one during the forenoon and the other during afternoon and also that alates became airborne between 5 a.m. and 6 p.m. and that settling was completed by 6 p.m. It is possible that the late take off of aphids around 8 a.m. in Kerala compared to Kalimpong area is probably due to dew formation and slow evaporation of dew drops in the morning hours due to the high relative humidity (70-75%) of the atmospheric air. In the Kalimpong area during this period in 1971, the relative humidity was 55-60% so that there would be quick evaporation of dew drops. El

Khidir (1963) showed that small insects like aphids can be virtually submerged in dew and this would undoubtedly delay the morning take off.

It is known that the alate activity is influenced by meteorological factors, but to understand the influence of weather, it is necessary to make long term studies extending from 2-3 years. From the present study confined to summer of 1979 it appeared that mean temperature and mean windspeed are inversely related to the catch of aphids. It is more probable that temperature has influenced the alate production, through its influence on the host plants of aphids and the comparatively low mean windspeed in the earlier part of study was condusive to the settling of aphids.

Further, the low windspeed in the forenoon would also lead to more aphid settling in the forenoon. But there is little evidence in the present study to indicate that impaction assisted by high windspeed appreciated the catch of alates.

Comparison of the number of alates caught belonging to *A. gossypii* and *A. fabae solanella* indicated that the former are by far more numerous than the latter. This was probably due to the fact that in Kariyavattom there are more host plants (82 species) of *A. gossypii* than of *A, fabae solanella* (7 species of host plants).

ACKNOWLEDGMENTS

The authors are thankful to Prof. K. M. Alexander for facilities in the Department, to prof. D. N. Raychaudhuri for making available valuable information from his unpublished papers and to Dr. A. K. Ghosh for his keen interest in this work. S. G. is also thankful to the Kerala University and UGC for financial assistance.

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LEGEND TO FIG. 1

Fig. 1 showing weekly meteorological data catches of aphids during the summer months of 1979 (late February to early May) at Kariyavattom in Kerala.

A. Weekly mean temperature (°C)

B. Weekly mean relative humidity %

C. Weekly mean wind speed kmph.

D. Weekly rainfall in mm.

E. Weekly aphid catch—forenoon

F. Weekly aphid catch—afternoon

STUDIES ON CERTAIN FACTORS AFFECTING ALATAE PRODUCTION IN GREEN PEACH APHID, *Myzus persicæ* Sulzer*

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ABSTRACT

Studies were carried out under controlled conditions to find out the effect of crowding, temperature and photoperiod on the production of winged forms in the green peach aphid *Myzus persicae* Sulzer. Among crowding and temperature variations, crowding of the aphid at higher densities and lower temperature favoured the production of alatae. Photoperiod was found to have no significant effect on alatae production.

INTRODUCTION

Aphids form one of the most important groups of vectors of plant diseases as the winged forms transmit many virus diseases. As early as 1923, Wadley studied the factors influencing alate production in the aphid ***Myzus persicae*** Sulzer which transmits more than 200 virus diseases in plants of 30 different families (van Emden ***et al.***, 1969). Several factors like crowding (Dickson and Laird, 1962; Lees, 1967; Mittler and Kunkel, 1971; Raccah *et al.*, 1971), temperature (Wadley, 1923; Schaefers and Judge, 1971), photoperiod (Johnson, 1966 b; Schaefers and Judge, 1971) host plants (Evans, 1938; Johnson, 1966 a; Schaefers and Judge, 1971) and composition of the food (Mittler and Dadd, 1966; Dadd, 1968; Mittler, 1971; Raccah ***et al.***, 1971, 1972) affect alatae production in several species of aphids. Hence a study was undertaken to find out the effect of crowding, temperature and photoperiod on the alatae production in apterous viviparous ***M. persicæ*** and the results are reported in this paper.

*** Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M. Sc. (Ag.) Degree.**

MATERIALS AND METHODS

The experiment was conducted under controlled temperature and artificial illumination with two 40 watts fluorescent lamps suspended 50 cm above the work bench. The apterae were reared from nymph to adult at 20 ± 1 °C and at 10 h photoperiod per day. The progeny of these adults were used in the experiments. The progenies were grown adults and were allowed to reproduce for one or two days and then were subjected to different treatments. Small leaf discs of 1.5 cm dia., punched out from leaves of chillies and floated in Hoagland—Snyder nutrient solution in small plastic vials, were used to rear the young ones produced by adults in different treatments. The leaf discs were floated in the solution upside down so that the aphid could feed from the lower surface of the leaf and the leaf discs were changed once in two days as the retention of leaf discs for longer periods resulted in rapid and considerable physiological changes in the host tissue.

To prevent the adults from moving away and from drowning in the solution, they were confined on the leaf discs using light weight micro-cages made of slices of plastic tubings with one end covered with muslin cloth. On each leaf disc one adult aphid was confined for 48 h to reproduce after which it was transferred to a fresh leaf disc. The progenies were collected from an adult indivisual for 10 days and the progenies were reared on the leaf discs till they grew up into fourth instar and observed for post-natal expansion.

EFFECT OF CROWDING

The adult aphid reared in isolation were selected and starved for two h and then were transferred to 1" × 1" plastic containers with leaf disc on moist cotton at the bottom. Batches of 5, 10, 15 and 20 aphids per sq. cm of leaf disc were allowed and this type of treatment was given for one day. The exposed aphids were then transferred to leaf discs and allowed to reproduce. A check was also maintained by directly transferring the isolated aphids on to the leaf discs and the experiment was replicated 4 times.

EFFECT OF TEMPERATURE AND PHOTOPERIOD

Adult aphids reared in isolation were given standard crowding treatments of 10 aphids per container for 24 h. They were then transferred to leaf discs and allowed to reproduce at different temperatures of 20°, 25° and 30 °C for ten days and at different photoperiods of 8 h, 10 h and 12 h per day. The experiment was replicated seven times for each treatment.

RESULT AND DISCUSSION

Effect of crowding :

Crowding at higher levels increased alatae production in ***M. persicae.*** Maximum percentage of alate progenies were produced when the parents were treated at crowding levels of 15 and 20 aphids which produced 18.68 and 17.57 per cent of alates respectively as against 0.19 per cent in control. The production of alatae might be due to tactile stimuli and this contributed to the production of more alates at higher densities (Lees, 1967). Though Dickson and Laird (1962) observed upto 99 per cent of alatae production under field conditions. the alatae production was low in the laboratory experiments. Besides, absence of sexual forms under Tamil Nadu conditions might also have attributed to this low percentage of alatae production.

TABLE 1

Effect of crowding on alate production in ***M. persicae***

Sl. No.	Treatments	Percentage of alate produced
1.	Isolated — Control	0.19 (2.81)
2.	— 5 aphids / cage	6.72 (15.02)
3.	— 10 aphids / cage	10.82 (18.70)
4.	— 15 aphids / cage	18.68 (25.61)
5.	— 20 aphids / cage	17.57 (24.76)

(Figures in parentheses are transformed values)

Comparison of significant effect :

	Level of significance	C. D. (P = 0.05)
Between treatments	0.01	1.59

EFFECT OF TEMPERATURE

Temperature had negative influence on the production of alates in *M. persicae* (Table 2). More alates were produced at lower temperatures while high temperature hampered the production of alates. Similar results were also obtained by Wadley (1923) on *M. persicae* and Schaefers and Judge (1971) on *Chaetosiphon fragaefolii* Ckll., but as in the previous case, the proportion of alates produced were less under the present findings. Abdul Kareem (1961) found that number of aphids trapped on the sticky traps was high when the mean temperature was low and this might be due to the production of more alates at lower temperatures so that more alates took to flight and got adhered to the trap.

TABLE 2

Effect of temperature on alate production in *M. persicae*

Sl. No.	Treatments	Percentage of alate progenies produced
1.	20 °C	19.12 (25.91)
2.	25 °C	16 56 (23.99)
3.	30 °C	15.28 (23.0[illegible])

(Figures in parentheses are transformed values)

Comparison of significant effect :

	Level of significance	C. D. (P = 0.05)
Between temperatures	0.01	1.39

EFFECT OF PHOTOPERIOD

No significant difference was observed on the effect of photoperiod in the production of alatae in *M. persicae* (Table 3) and percentage of alates produced were almost equal in all treatments. Though Tsitsipis and Mittler (1977) reported lesser photoperiod favouring production of alate forms, it was not so in the present experiments.

TABLE 3

Effect of photoperiod on alate production in *M. persicae*

Sl. No.	Treatments	Percentage of alate progenies produced
1.	8 h photoperiod	19.37 (26.06)
2.	10 h photoperiod	18.88 (25.72)
3.	12 h photoperiod	19.25 (25.99)

(Figures in parentheses are transformed values)

Comparison of significant effect :

	Level of significance	C. D. (P = 0.05)
Between photoperiods	N. S.	—

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EFFECT OF TEMPERATURE ON THE FECUNDITY OF FIVE SPECIES OF APHIDS

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ABSTRACT

Freshly emerged adult apterous virginoparae of five species of aphids viz., *Aphis nerii* Fonsc., *Lipaphis erysimi* (Kalt.), *Macrosiphoniella sanborni* (Gillette), *Pentalonia nigronervosa* (Coq.) and *Rhopalosiphum maidis* (Fitch) were maintained on the leaves of their host plants, *Calotropis gigantea, Brassica oleracea var capitata* (Cabbage), Chrysanthemum, banana and maize respectively, to test the fecundity of ten specimens in five days at 15, 20, 25, 30 and 35 °C at 75 ± 2% RH. It was found that the aphids died at 35 °C, while the highest fecundity was recorded at 30 °C and the lowest at 15 °C.

INTRODUCTION

There are always some restrictions laid upon the living organisms. The changing environment is the main restriction with which a correlated response is marked in the organism. The degree of response depends upon the degree of change of environmental factors. Temperature has an important influence upon the body metabolism and physicochemical phenomena of life.

Various workers have established different temperature ranges for the minimum, optimum and maximum rates of aphid reproduction. Hunter (1909) found the optimum to be 68°F or 20°C, with reproduction gradually decreasing until a minimum occurred at 84°F or 29°C. Headlee (1914) recorded results with constant temperatures of 50, 60, 70, 80 and 90°F or .0, 15.5, 21, 26.5 and 32°C and found the optimum to be between 71° and 73°F or 21.8 and 22.8 °C. Singh and Wood (1963) described the effect of temperature on the fecundity of two strains of the green bug, *Toxoptera graminum* (Rondani).

The present paper reports the result of our investigation on the effect of temperature on the fecundity of five different species of aphids, namely, ***Aphis nerii*** Fonsc.. ***Lipaphis erysimi*** (Kalt), ***Macrosiphoniella sanborni*** (Gillette), ***Pentalonia nigrovervosa*** (Coq.) and ***Rhopalosiphum maidis*** (Fitch.).

MATERIALS AND METHODS

Laboratory cultures of the five species of aphids viz., ***L. erysimi***, ***M. sanborni***, ***P. nigronervosa***, and ***R. maidis*** were maintained at 27±2°C and 65±3% RH on the fresh leaves of their respective host plants i.e., *Calotropis*, Cabbage, Chrysanthemum, banana and maize. Ten freshly emerged adult aptrae of each of these groups were taken in glass petri dishes and kept inside a B.O.D. incubator at constant temperature ranging from 15 to 35°C at a difference of 5° i.e., 15°, 20°, 25°, 30°, and 35°C. At 24 hours intervals the nymphs produced were counted, the number recorded and fresh leaves were supplied to the aphids.

RESULTS AND DISCUSSION

The total number of nymphs produced by ten aphids from each of the five species for a time period of five days at different constant temperature are presented in Table 1.

Reproduction is highly influenced by changing temperature. An increase in the nymphal production was marked with each 5 degree rise in temperature above 15°C until the optimum for reproduction was reached. From the data it is seen that at 30 °C, there was maximum production of nymphs and hence 30°C is the optimum for fecundity of all these five aphid species. But when the temperature was raised to the next higher degree i.e., 35°C, all the aphids died within a day.

An another experiment was conducted by increasing 1°C each time above 30°C for each of the five species of aphids. It was observed that there was a gradual decrease in fecundity with every 1° rise in temperature above 30 °C (Table 2).

At 34°C the production was totally zero and even some of them died. At 35°C survival was nil.

Thus it appears there is a definite response in all these aphid species to different temperatures. An increase or decrease acts as a stimulus. Increased activitv is brought about by raising the temperture upto 30°C after which inhibition occurs. Similarly decrease in activity occurs with lowering of temperature to 15°C.

TABLE 1

Total number of nymphs produced by five species of aphids at different constant temperature and 75 ± 2 % RH.

Temperature (°C)	Total number of nymphs produced in 5 days				
	A. nerii	*L. erysimi*	*M. sanborni*	*P. nigro-nervosa*	*R. maidis*
15	3	2	2	3	4
20	6	13	6	10	6
25	13	19	25	15	12
30	21	26	30	20	30
35	0	0	0	0	0

TABLE 2

Nymphs produced by five species of aphids maintained at different temperatures above 30 °C and 75 ± 2 % RH.

Temperature (°C)	Nymphs produced				
	A. nerii	*L. erysimi*	*M. sanborni*	*P. nigro-nervosa*	*R. maidis*
30	21	26	30	20	30
31	15	12	15	11	13
32	6	5	7	4	5
33	2	2	3	2	1
34	0	0	0	died	died
35	died	died	died	died	died

With increase in temperature, larger number of young are produced certainly due to an incrense in the rapidity of growth and a speeding up of the process of reproduction. Similarly, with a decrease in temperature, reproducion it inhibited due to the reduced rapidity of growth.

The present result is in accord with the findings reported by Weed (1927) who found that the processes of metamorphosis, reproduction and longevity in ***Myzus persicae*** Sulz., are proportional to temperature and humidity. An increase in reproduction is corelated with the increase in temperature and the reverse is quite apparent with its decrease. Dahm and Painter (1940), and Hackerott and Harvey (1959) had similar observations in the aphid species, ***Therioaphis maculata*** (Buckton) and ***Macrosiphum pisi*** (Harris) respectively. Headlee (1914) described certain groups of insects where high temperature increased the daily rate of reproduction. Singh (1963) showed in two strains of green bug, ***Toxoptera graminum*** (Rondani) that there was an increase in reproduction with increased temperature and the maximum was at 75°F or 24°C after which reproduction retarded gradually and at 100°F or 38°C, fecundity was nil. It is probable that slight variation in temperature range may be due to the use of different host material and different insect strains.

Harries (1939) examined the rate of oviposition with reference to temperature in ***Epilachna varivestis*** Muls., ***Drosophila melanogaster*** Meig., and ***Eutettix tenellus*** (Bak.) and analysed the whole data in the light of different temperature formulae for evaluating the accelerative influence of temperature. He concluded that the rate of ovipositition, although increased by rise of temperature to a certain point beyond which it is retarded, is not proportional to temperature in a linear fashion so as to be represented by a straight line and instead the data observed follow S-shaped curves similar to other physiological activities. The data of present investigation also follow the same S-curves. This together with the result of Harries (1939), when compared with the four well known formulae of temperature of Krough, Van't Hoff, Arrhinus and Betehradek, show the maxjmum coincidence with that of Van't Hoff (Harries, 1939).

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EFFECT OF AGGREGATION ON THE BIOLOGY OF THE LOTUS APHID *RHOPALOSIPHUM NYMPHÆÆ* (LINN.)

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ABSTRACT

Rhopalosiphum nymphaeae (Linn.) were reared in the laboratory on lotus leaves at 27 ± 3°C and 65 ± 5% RH to study the effect of aggregation on its biology. Aggregated nymphs showed lower mortality and more rapid development compared to higher mortality and slower development in isolated ones. The duration of nymphal instars was more variable in isolated nymphs, whereas crowding induced an orderly moulting rhythm. Apterous virginoparae emerging from crowded nymphs weighed less in comparison to those developing from isolated ones. Apterous adults kept under crowded conditions produced lesser number of nymphs than the isolated ones. The mean life span was not affected by aggregation or isolation.

INTRODUCTION

Aphids are seldom found distributed uniformly over the host-plant. They are usually concentrated to a greater or lesser extent on specific areas of the host. New born nymphs are deposited very close to each other. Crowding may affect aphids directly as a result of mutual stimulation or indirectly as a result of demands on the food supply. Bonnemaison (1967) reports that nymphs of *Megoura viciae* (Buckton) tend to aggregate on the host-plant *Vicia fabae* whereas, the adults remain scattered. Lees (1967) and Bonner (1972) have made significant contribution to our knowledge about the effect of crowding and production of different nymphal forms in *M. viciae*, while Sutherland (1969) conducted similar experiments on *Acyrthosiphon pisum* Harris. Dixon (1971) records that *Aphis fabae* Scop., reared on a leaf of bean in a small aggregation are heavier at maturity than isolated nymphs reared on uninfested leaves. The present paper reports our findings on the effect of aggregation on the lotus aphid, *Rhopalosiphum nymphaeae* (Linn.).

MATERIALS AND METHODS

A culture of *R. nymphaeae* was maintained in the laboratory at 27 ± 3 °C and 60 ± 5 % relative humidity on lotus leaves, *Nelumbium speciosum* during February 1978. In order to measure the effect of crowding, nymphs dropped by freshly emerged adult apterous virginoparae were employed after 12 hours of birth. The 12-hour old nymphs were caged in petri dishes on pieces of healthy lotus leaf which were replaced by fresh pieces every 24 hours. Experiments were conducted at three levels of crowding viz., one nymph per cage, ten nymphs per cage and thirty nymphs per cage. Weights of aphids were determined in an electro-balance. For measurements, specimens were stored in 70% alcohol and mounted in Euparol.

RESULTS

The nymphs attained adulthood in six days. Two phases of weight change were noted, the first ending with the emergence of the apterous adult virginoparae through four nymphal instars and the second, the adult phase. There was a significant difference between the rate of growth (weight gain during the nymphal period) of aphids reared singly and those aggregated at thirty per cage (Fig. 1). No significant difference was noticed between the rate of growth of aphids reared singly and those in aggregation of ten per cage.

Observations on the speed of nymphal development was achieved by recording the proportion of nymphs in each instar each day (Fig. 2). On only one day (3rd day) (Fig. 2A) was there more than one instar present when nymphs were reared under crowded (30 per cage) conditions, whereas in the case of lonely reared nymphs, more than one instar was always found on any day (Fig. 2B). This indicates that, speed of nymphal development is variable in aphids reared in isolation whereas aggregation induces a synchronous moulting rhythm. Furthermore, development is quicker when nymphs are kept under crowded conditions, the adults are produced earlier (Fig. 1) and weigh less in comparison to those reared in isolation.

The second phase includes weight change in the nymph developing into adult where the uniform change of nymphal growth was replaced by a non-uniform pattern. In order to know the effect of crowding both on nymphs and adults, further data were obtained by maintaining high or low densities in the nymphal stage, adult stage or throughout the aphid's life from birth till death. For this experiment four different batches of aphids were placed under observation, such as, (1) nymphs isolated after birth till they reached adulthood, (2) nymphs reared in isolation and kept under crowded condition after the fourth moult, (3) nymphs reared in crowded condition and reared in the same condition after adulthood, and (4) nymphs reared under crowded condition and isolated after final moult. Dead aphids in the crowded cages were replaced by aphids from another crowded culture to maintain the population pressure.

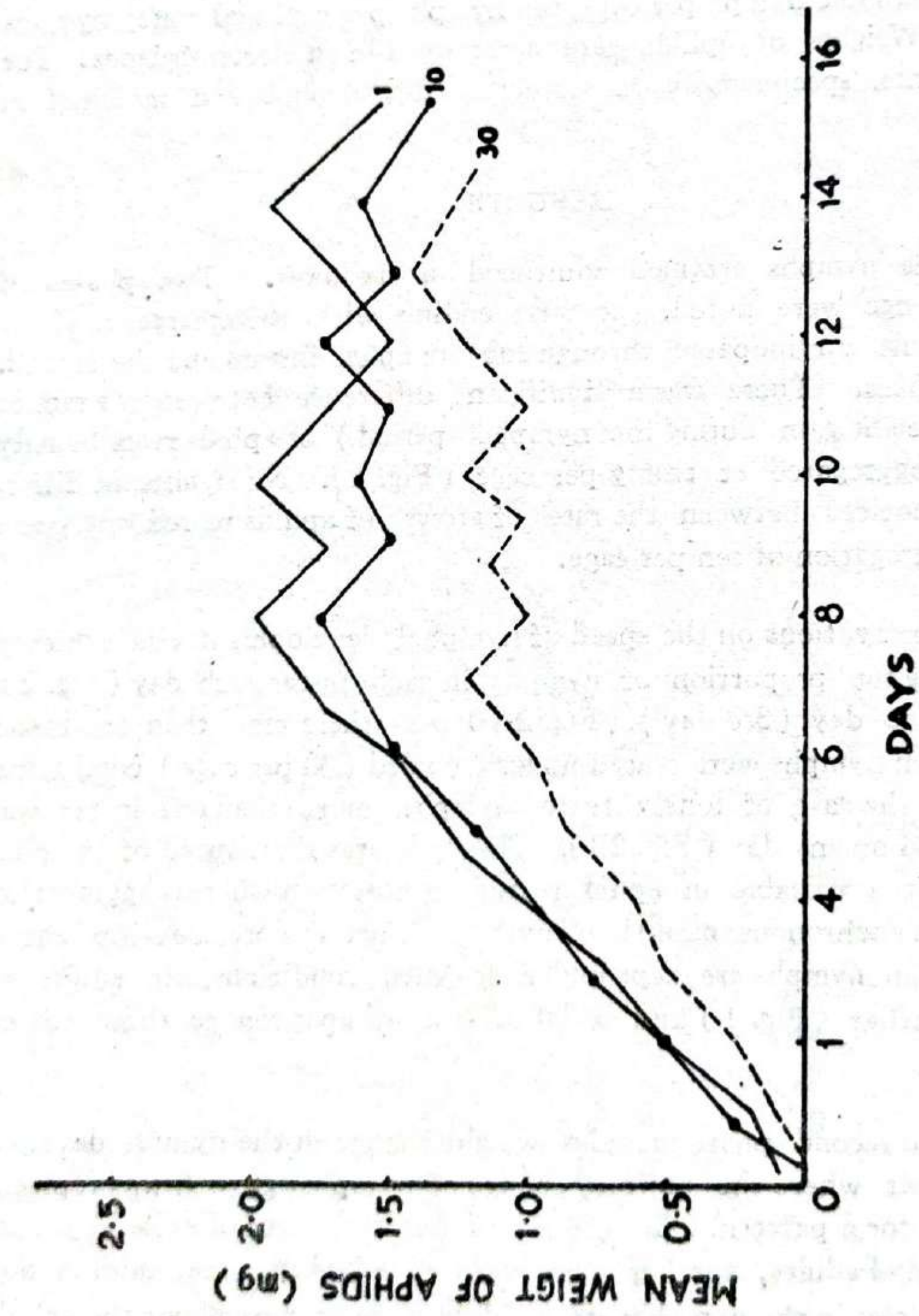

Fig. 1 - Changes in the weight of aphids at three densities with time. ——— thirty aphids per cage, •——• ten aphids per cage, ——— one aphid per cage.

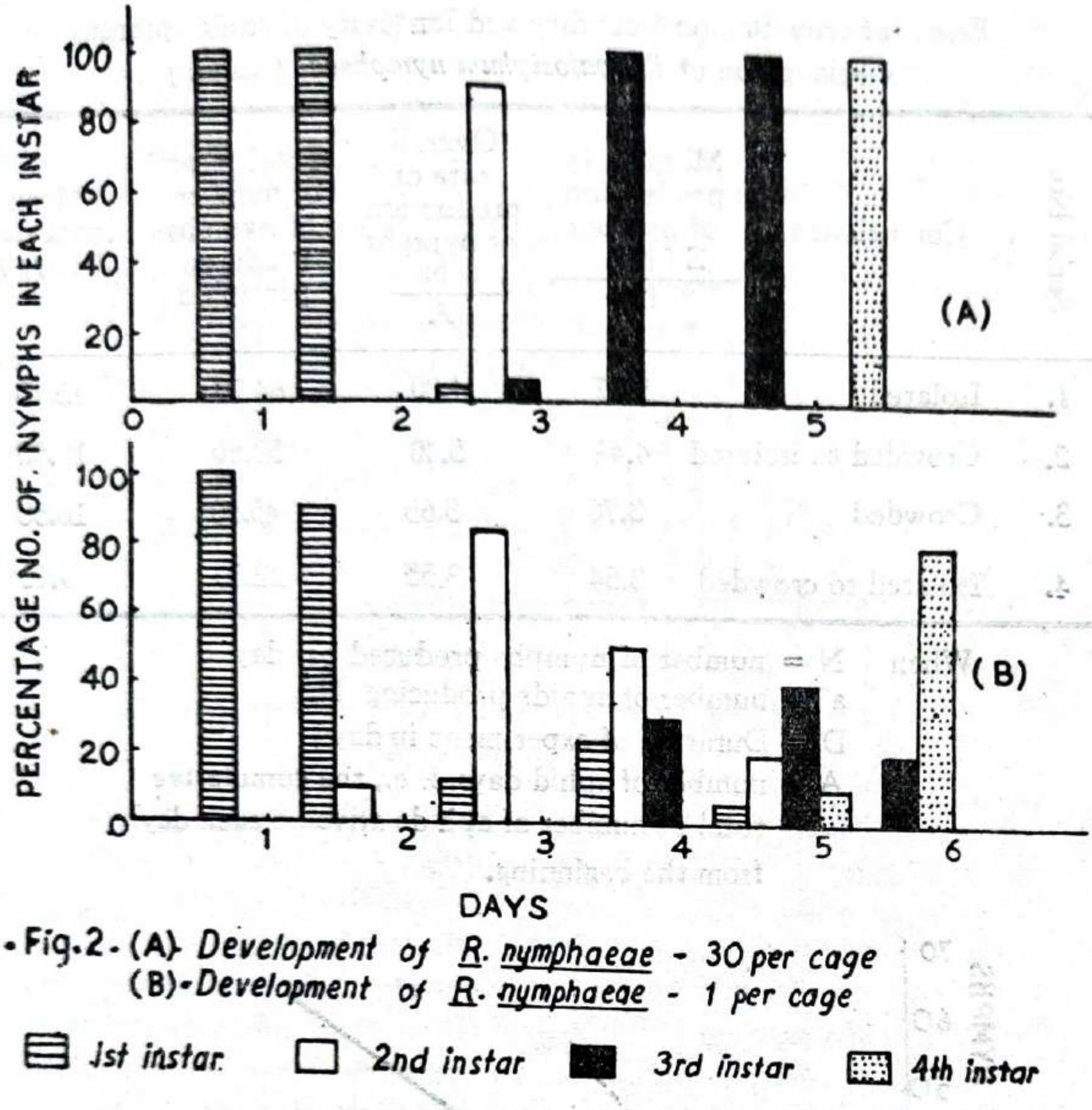

Fig.2. (A) Development of *R. nymphaeae* - 30 per cage
(B) Development of *R. nymphaeae* - 1 per cage

It was observed that crowded adults produced nymphs at a lower rate than isolated adults irrespective of their previous condition of nymphal development (Table 1 and fig. 3).

The mean longevity shows that it is independent of aggregation and isolation. Moreover, aphids exposed to changing conditions at the end of the nymphal period appear to have shorter lives than aphids maintained under crowding or isolation. The relationship between the weight of adult aphids and their fecundity has been presented in Fig. 4. It is demonstrated that crowded aphids not only have lower fecundity, but also are lighter in weight.

TABLE 1

Effect of crowding on fecundity and longevity of adult apterous virginoparae of ***Rhopalosiphum nymphaeae*** (Linn.)

Serial No.	Conditions	Mean daily production of nymphs $\frac{\Sigma(N/a)}{D}$	Overall rate of production of nymphs $\frac{N}{A}$	Total mean of number of nymphs produced per aphid	Mean longevity (days)
1.	Isolated	5.67	4.80	64.70	15.10
2.	Crowded to isolated	4.43	5.40	52.80	10.50
3.	Crowded	3.76	3.65	45.50	16.50
4.	Isolated to crowded	3.54	3.55	22.50	9.10

When N = number of nymphs produced per day
a = number of aphids producing N
D = Duration of experiment in days
A = number of aphid days, i. e., the cumulative total of number of aphids alive on each day from the beginning.

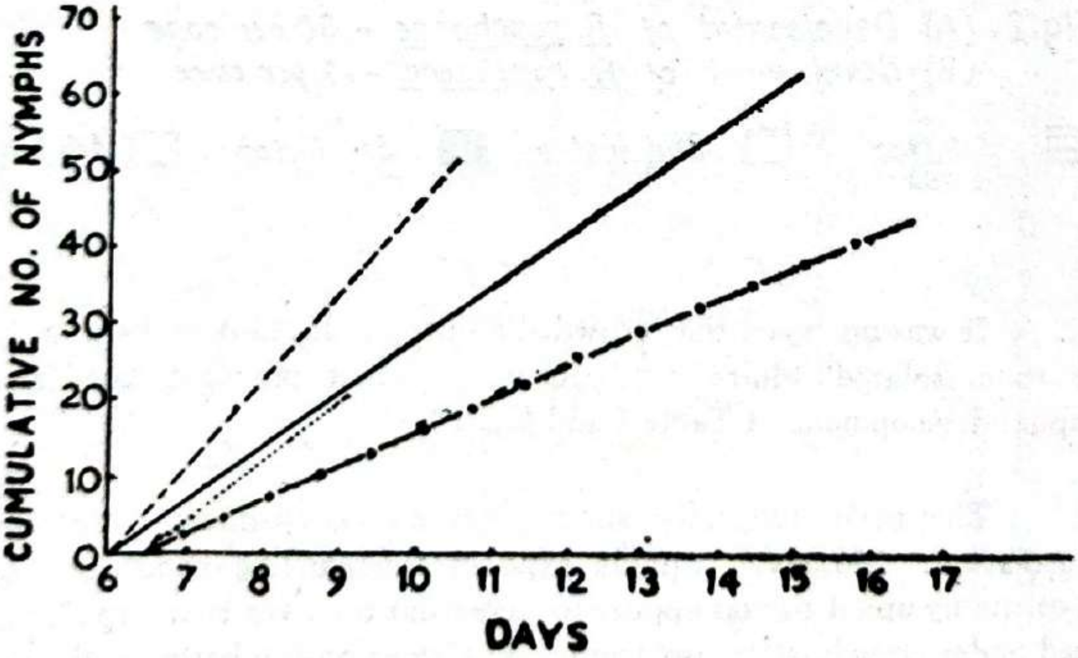

Fig. 3 - *Cumulative daily mean production of nymphsreared in various conditions. —— isolated, ----- crowded to isolated, —·—·— crowded, ... isolated to crowded.*

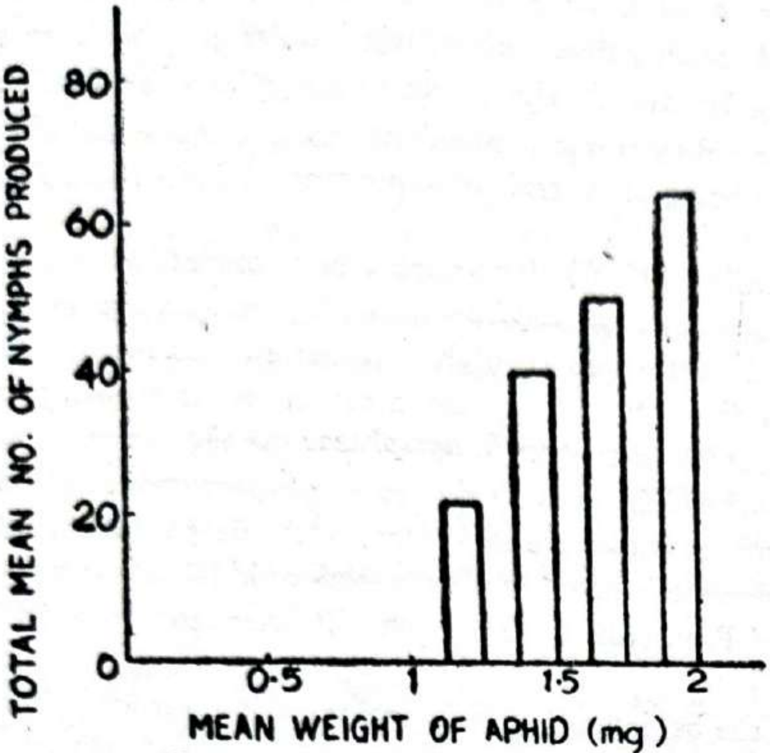

Fig. 4 - *Relationship between adult weight and fecundity.*

DISCUSSION

In *R. nymphaeae* the adult stage is reached earlier when the nymphs are maintained under crowded conditions (Fig. 2A and 2B). The adults produced under such conditions weigh less than those reared in isolation, a finding which confirms those of Murdie (1969a) in *A. pisum* and Bonner (1972) on *M. viciae*, but contradicts that of Dixon (1971) on *A. fabae* where adult aphids are heavier when the nymphs are reared in crowded condition. Rinvay (1966) also suggested the same in a lepidopteran insect, *Spodoptera littoralis* Boisd., while Wharton (1967) found the average weight of adults of the American cockroach tends to decrease with increase of population density of larvae.

Under crowded conditions the rate of production of nymphs by adult apterous virginoparae of *R. nymphaeae* is lowered. Similar observations were made by Bonner (1972) in *M. viciae* and by Rinvay and Meisner (1966) in the lepidopteran *Spodoptera littoralis.* But this was not due to the light weight of adults produced from crowded nymphs. It would appear from table 1 that light adults resulting from nymphs kept under crowded conditions when isolated, produced nymphs almost at the same rate as heavy adults in isolation. The statements by Murdie (1969b) and Dixon (1971) that large adults give birth to more nymphs perhaps must be due to the effect of the colony as a whole on fecundity. Therefore fecundity is not dependent upon the size of adults, its subsequent history being of overriding importance (Bonner and Ford, 1972).

Murdie (1969a) along with other workers has suggested the possibility of a pheromone in *A. pisum* affecting stimulation of growth at low densities and inhibition at higher densities. Bonner (1972) offered the same explanation for the synchronization of nymphal moulting in *M. viciae.* It seems likely that in *R. nymphaeae* the regulation of adult fecundity independent of weight may be due to some pheromone action. However, the present observations are in accord with the possibility of 'continuous gregarious communication' between the aphids, a view put forward by Kennedy and Fosbrooke (1971), and Bonner and Ford (1972).

At the beginning of infestation, the apterous adult are at a low number on the host-plant and undergo a rapid rate of reproduction establishing a large colony and exploiting all possible resources. But at higher densities, the rate of reproduction is lowered and definitely this reduces the possibility of over-exploitation of the host-plant. These features of aphid biology probably have an adaptive significance.

Way and Banks (1967) reached at the conclusion that *A. fabae* possesses self regulatory mechanisms which control the population growth and to this Bonner (1972) agreed for *M. viciae.* The same explanation also could be offered for *R. nymphaeae.*

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The Aphids : 36.42

ON THE COLOUR PREFERENCE OF FIVE SPECIES OF APHIDS

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ABSTRACT

The colour preference of apterous virginoparae of ***Aphis craccivora*** Koch, ***Aphis gosaypii*** Glover, ***Aphis nerii*** Fonsc., ***Lipaphis erysimi*** (Kalt.) and ***Rhopalosiphum maidis*** (Fitch.) was studied by releasing 100 aphids in the colourless centre of petri dishes 17 cm in diameter with nine colours viz., violet, indigo, blue, green, yellow, orange, red, black and white arranged in various combinations. All the aphid species exhibited highest preference for yellow and the least for violet and black, while ***R. maidis*** showed equal preference for yellow and orange.

INTRODUCTION

Behavioural evidence supports the interpretation that many insects can distinguish between different wave lengths and hence possess true colour vision. In his pioneering work on insect colour vision, von Frisch (1914) showed that honeybees are able to differentiate accurately between several major categories of colour, such as, yellow, blue, green, purple, orange and violet. Knowledge of colour response of aphids is important in interpreting the basic biology and behaviour of these insects. Information about colour responses of aphids may also find practical application in designing traps for sampling population, developing technique for culturing them and in understanding host-plant selection by these insects. Moericke (1950) for the first time discovered that alate aphids are attracted to yellow colour and since then yellow traps are used for catching aerial aphids in the field. Although a number of papers have been published dealing with the colour response of alate aphids, very little is known about the behaviour of apterous aphids in this regard.

Medler (1966) discovered that apterous morphs of *Rhopalosiphum maidis* (Fitch.) are attracted to yellow water pan. Cartier (1966) reviewed the extensive literature on aphid response to colour in the laboratory. Medler and Ghosh (1968) placed yellow pan water, wind and suction traps at different places in U. S. A. and observed the presence of apterous aphids in them. Behura *et al* (1975) observed the colour preference of *Aphis nerii* Fonsc., in the laboratory. Kieckhefer *et al* (1976) have reported the colour response of all life stages of some cereal aphids.

The present paper reports the results of our studies of colour preference of five species of apterous virginoparae, viz., *Aphis craccivora* Koch., *Aphis gossypii* Glover, *Aphis nerii* Fonsc., *Lipaphis erysimi* (Kalt.) and *Rhopalosiphum maidis* (Fitch) and their nymphal instars.

MATERIAL AND METHODS

Cultures of *A. craccivora*, *A. gossypii*, *A. nerii*, *L. erysimi* and *R. maidis* were maintained in the laboratory at 27 ± 3 °C and 62 ± 2% RH on their respective host plants, namely, bean, china rose (*Hibiscus rosasinensis*), *Calotropis*, radish and maize. The apterous forms and their four nymphal stages were selected for study of colour response.

Ten glass petri dishes about 17 cm in diameter and 2.5 cm in depth were oil painted with nine different colours in equal areas, viz., violet, indigo, blue, green, yellow, orange, red, black and white and these colours were arranged in ten different combinations. The central portion of the petri dishes was left colourless. A small portion of coloured areas (for aphid's movement to different colours) and the central portion were kept gum free and the rest was smeared with gum. One hundred aphids of any particular stage of each species were released in the central colourless area with the aid of a fine brush. Aphids were found moving to different coloured areas and the results were recorded at the end of six hours. This was repeated for all the nymphal stages and adults of all the five species. Each experiment was repeated three times. The aphid specimens trapped in different coloured areas were counted. Aphids lying on borders of two colours or left in the central colourless area were not taken into account.

RESULTS AND DISCUSSION

Data on the colour preference of the different species of aphids and their nymphal instars are presented in Table 1. It shows that all the five species of apterous virginoparae and their respective nymphal stages have the highest preference for yellow colour and the least for violet and black. The preference for yellow increases in an ascending order as the

TABLE 1

COLOUR PREFERENCE (%) OF FIVE SPECIES OF APHIDS

		Violet	Indigo	Blue	Green	Yellow	Orange	Red	Black	White
Aphis nerii										
Itstar	I	6.2	9.4	9.1	12.2	22.5	15.2	9.2	5.2	10.0
	II	5.6	8.0	9.3	15.0	26.3	17.3	6.8	4.0	7.0
	III	4.8	7.7	10.8	12.9	31.6	15.6	6.8	4.0	5.8
	IV	4.6	6.8	11.5	13.9	33.0	13.5	6.3	3.9	6.6
	Adult	3.7	6.4	9.9	12.9	35.0	16.9	6.2	2.5	6.5
Aphis craccivora										
	I	8.0	10.2	10.3	11.3	19.6	11.9	9.8	8.2	10.7
	II	7.2	10.5	11.2	10.3	22.0	12.0	10.2	7.1	9.5
	III	7.0	10.1	8.0	9.2	26.2	13.0	11.0	6.5	9.0
	IV	6.0	9.6	9.9	9.4	28.2	9.6	10.1	6.2	11.0
	Adult	4.2	9.5	9.4	9.8	30.5	12.3	10.3	5.0	9.0
Aphis gossypii										
	I	7.2	10.0	10.5	9.4	25.7	9.8	10.1	7.0	10.2
	II	4.7	6.8	8.7	13.8	28.7	10.6	10.2	6.0	10.9
	III	4.7	9.2	10.7	9.4	31.0	10.6	10.4	6.0	8.6
	IV	3.8	9.9	8.8	10.7	34.5	9.6	9.4	6.0	7.3
	Adult	3.0	9.5	8.8	8.6	40.4	8.0	12.2	4.0	5.5

Table 1 (*Contd.*)

Colour preference (%) of five species of aphids

	Violet	Indigo	Blue	Green	Yellow	Orange	Red	Black	White
Rhopalosiphum maidis									
I	8.6	11.7	10.6	10.4	13.0	12.0	11.7	8.9	12.1
II	8.0	10.2	11.0	11.8	14.4	15.0	11.0	7.0	11.6
III	4.8	12.0	10.3	11.1	16.0	16.0	12.8	6.4	11.6
IV	4.5	10.0	10.6	11.8	16.8	17.0	11.4	6.4	11·5
Adult	4.5	12.0	11.3	9.8	18.0	18.0	10.8	5.9	9.5
Lipaphis erysimi									
I	7.6	8.3	10.6	15.3	24.0	9.1	9.9	7.8	9.4
II	7.6	9.4	9.8	12.0	25.0	9.0	10.2	7.8	9.2
III	7.2	9.0	7.7	14.9	26.0	13.3	10.5	7.7	9.0
IV	6.2	9.0	9.6	11.1	28.0	10.3	9.1	7.7	9.0
Adults	6.0	8.6	10.1	9.0	32.0	11.2	9.6	5.5	8.0

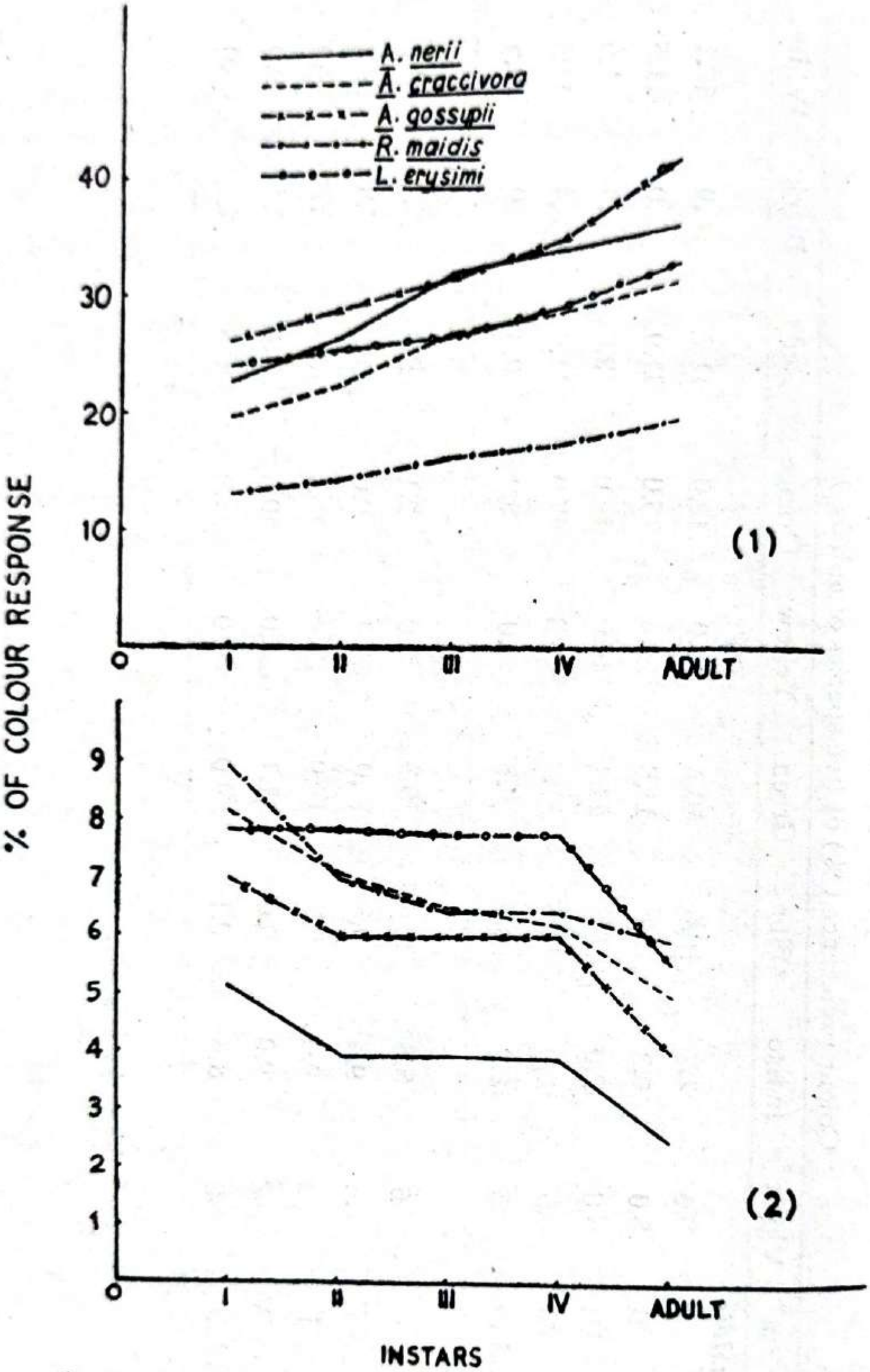

Fig.1 - *Ascending response to yellow from Ist instar nymph to adult in five species of aphids.*

Fig.2 - *Discending response to black from Ist instar nymph to adult in five species of aphids.*

aphids pass their life cycle from the first nymphal instar to adult (Fig. 1). Similarly, attraction for the least preferred colours i. e., black and violet decreases n a descending fashion from the first nymphal to adult instar in almost all the aphid species (Fig. 2). Of the five species, percentage of response to yellow colour is highest in *A. gossypii* and lowest in *R. maidis*. In *R. maidis* all the instars exhibit equal perference for yellow and orange.

Very interestingly, all the five species of aphids as well as their nymphal instars were attracted to yellow irrespective of the different colour arrangement in the ten different petri dishes. It was also interesting to note that aphids were maximum in number in yellow when yellow was nearer black or violet. It may be due to the migration of aphids from the least preferred colours to adjacent yellow.

After reviewing literature on aphid response to colour, Taylor and Palmer (1972) concluded that generally aphids feeding on dicotyledons are attracted to yellow and those on monocotyledons are not. But their observation is based mainly on the results of field-trapping of aphids where the spectral and light intensity ranges were usually not consistant. Eastop (1955) has shown that the response of *R. maidis* to yellow varies with the intensity of sunlight. Zettler (1967) concluded that the response may vary on different occasions.

In our experiments with five species of aphids, except for one, all the other four namely *A. gossypii*, *A. nerii*, *A. eraccivora*, and *L. erysimi* showed decided preference for yellow and the preference is consistant through all the instars. Significantly, *R. maidis* showed an equal preference for yellow and orange. Differences among the mean number of aphids responding to the preferred colour and the number under other colours are generally highly signifficant ($P < 0.01$), but differences among numbers under colours other than the preferred were usually not significant ($P > 0.05$), a result fairly agreeing with the findings of Kieckhefer *et al* (1976) on four species of aphids viz., *Schizaphis graminum* (Rondani), *Macrosiphum avenae* (F.), *Rhopalosiphum maidis* (Fitch.) and *Rhopalosiphum padi* (L.).

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INCIDENCE PATTERN AND POPULATION COMPOSITION OF *LIPAPHIS ERYSIMI* (KALTENBACH) ON MUSTARD AND RADISH

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ABSTRACT

During early November, immigrant alates of *Lipaphis erysimi* (Kalt.) appear on mustard when the plants are still in the seedling stage. Population build up is quite rapid and incidence of the pest reaches peak during mid-December and high level of population is maintained for quite some time. Decline in population usually begins from February and is at a very low ebb in March-April while on radish appearance of the aphid species occurs about a month later in early December and the peak of incidence takes place in early January. In general, the proportion of apteroid viviparae is more during the early growth phase of the population till the peak is reached. Thereafter, the proportion of the alatoid viviparae increases and ultimately predominates over the apteroid morphs. This trend in the change of population composition is found on both mustard and radish.

INTRODUCTION

The mustard crop very often suffers serious loss due to the infestation of *Lipaphis erysimi* (Kalt.). The aphid species appears to be rather host specific as only plants belonging to Crucriferae are infested.

Reports of work on *L. erysimi* other than control are those on the biology in Punjab by Sidhu and Singh (1964) and in Orissa by Rout and Senapati (1968). Seasonal history and biology of this insect have also been reported briefly by Das (1918) from Lahore (Pakistan), George (1928) from Çoimbatore and Deshpande (1937) from Poona. Rattanlal (1957) dealt with the conditions governing the production of alate. Kundu and Pant (1967a, 1967b and 1968) have studied various aspects of relationship of the aphid species with its host.plants including the effect of age of host-plants on the suspectibility to the attack of the aphid. The present investigation deals with population studies of *L. erysimi* on mustard and radish during 1974—75.

MATERIALS AND METHODS

Samples of *L. erysimi* for population count were collected from fields of mustard and radish at weekly intervals. Ten samples were collected on each occasion from each of the crops at random and were stored in vials containing 70% alcohol. During the early vegetative phase of the crops collection of aphids were made from one-tenth of the area of leaves of radish and one-fourth of leaf area of mustard. Later, with the putting forth of inflorescence or elongation of shoot in mustard (from the second sampling in each of the crops) samples from the apical 3 cm of the shoot were collected, while in case of radish collection from leaves was continued till harvest. Counting of specimens was done under binocular microscope. While counting seperate accounts were maintained for the different stages and morphs of the aphid species. The observations were continued till the crops were mature. The crops were sown in mid October, 1974 and normal cultivation practices were followed.

RESULTS AND DISCUSSION

a) *Pattern of incidence* (Fig. 1)—

During early November, when mustard plants are still in the seedling stage, immigrant alates of *L. erysimi* appear on the plants and noticeable occurence on the plants are recorded from mid-November. The population of aphids increases in quick pace to attain the peak during mid-December. Then follows a period of rapid decline of population to become quite negligible when mature.

On radish *L. erysimi* appears about a month later than on mustard i.e., during early December to reach the peak of incidence during early January. Then ensues a period of rapid decline in population. On leaves the decline of population is rather quick than on the growing apical portion. The apical portion of the plant attracts the vagrant alates which built up population there and a substancial population also crawls up to the apical portion from the leaves of the same plant and multiply there to add further to the existing population. These phenomena cause quick build up of population on the apical portion of the radish plants and thus the population inflates in rapid strides to occupy all habitable space within

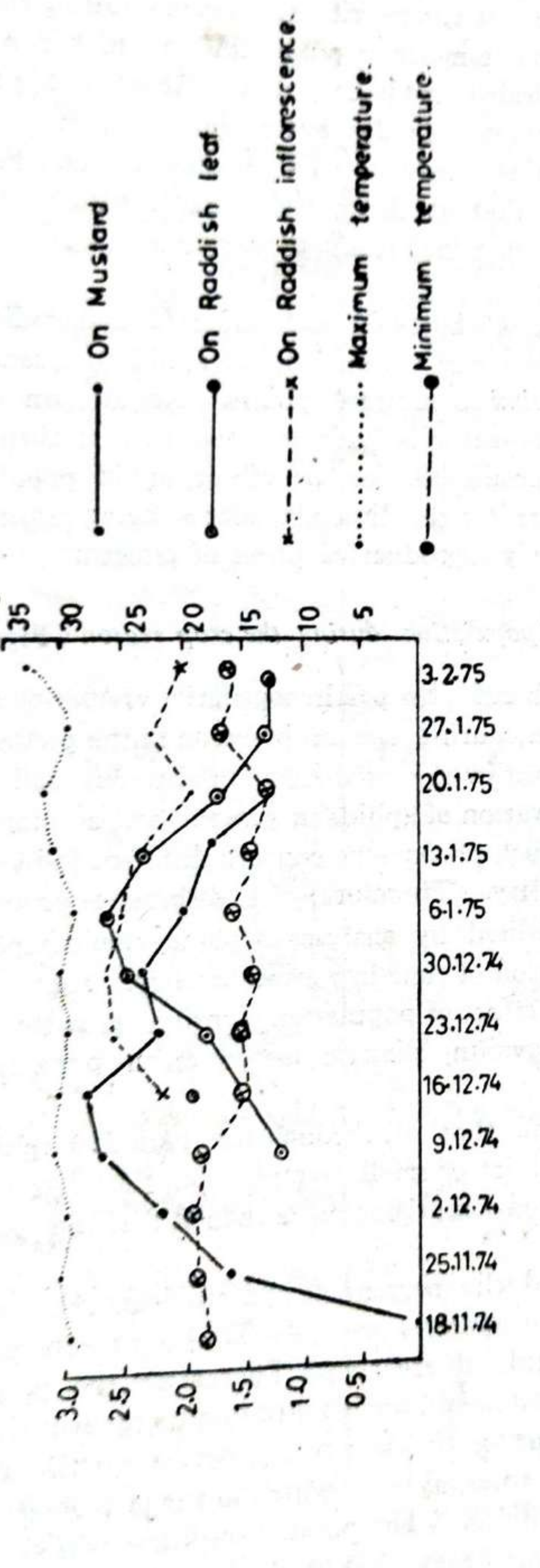

FIG. 1 Population pattern of *Lipaphis erysimi* on different host plants.

a short span of time. A reverse situation occurs during the same period on the leaves. The maintenance of population of a higher order for a longer duration on the apical portion than on the leaves is due to the fact that this part of the plant provides better nourishment to the aphids for a longer period than the leaves. The population on the leaves reaches maximum earlier to that at the apical growth region of the plant and becomes suitable for sustained feeding and turn yellow.

In spite of availability of both mustard and radish plants during the same period, the early occurrence of aphid on mustard indicates the preference of *L. erysimi* to mustard plants. Acquisition of radish plants later during the same season is due to the fact that by then mustard plants gradually become unsuitable for growth of aphid populations, the next available food plant for the dispersing alates being radish which is still in the vegetative or early reproductive phase of growth.

b) *Composition of population during the crop season* (Figs. 2, 3)—

L. erysimi breeds by parthenogenetic viviparity during the period of its occurrence i.e., during the crop season in the plains of India. Polymorphism is exhibited by the production of apterous and alate viviparae. Dispersal and migration of aphids in general are accomplished by alates particularly when such phenomena concern different individuals of the host plants or the locality. Therefore, the dispersive propituousness of this aphid can be visualised by analyses of population composition in colonies during a certain period of time in a given locality. Such analyses may also throw light on the effect of population density, growth phase of crop and influence of the prevailing climatic factors on the population.

It was found that all through the period of aphid infestation the percentage of population of small nymphs i.e., the first and second instar nymphs predominated comprising more than 50% of the population.

On mustard the percentage of alatoid morphs were much lower (1.5—6.5%) than the apteroid ones (8—33%) during the period from second observation to seventh observation. Thereafter the percentage of alatoid morphs gradually increased (6—18%) to dominate over that of the apteroid ones (0-9%) and during the last two observations this percentage (18%) much surpassed the apteroid ones which in the last observation was wholly composed of alate adults. The population composition of the first observation simulated more or less that of the last observation.

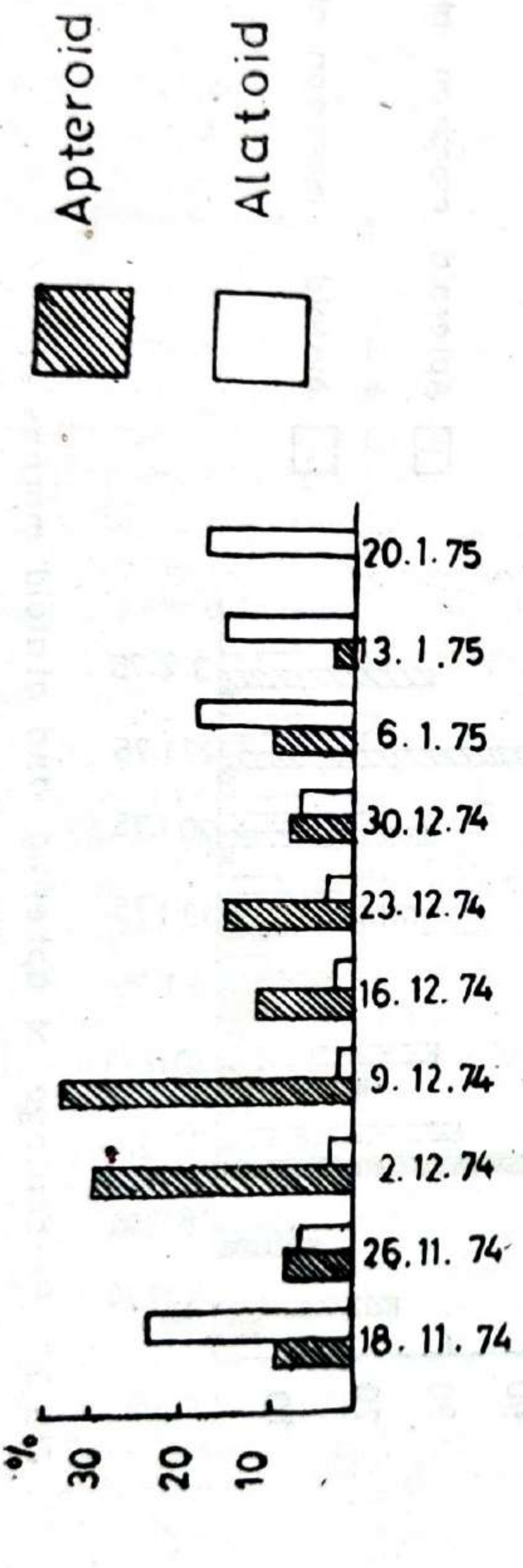

Fig. 2 Percentage of apteroid and alatoid morphs of Lipaphis erysimi on Mustard.

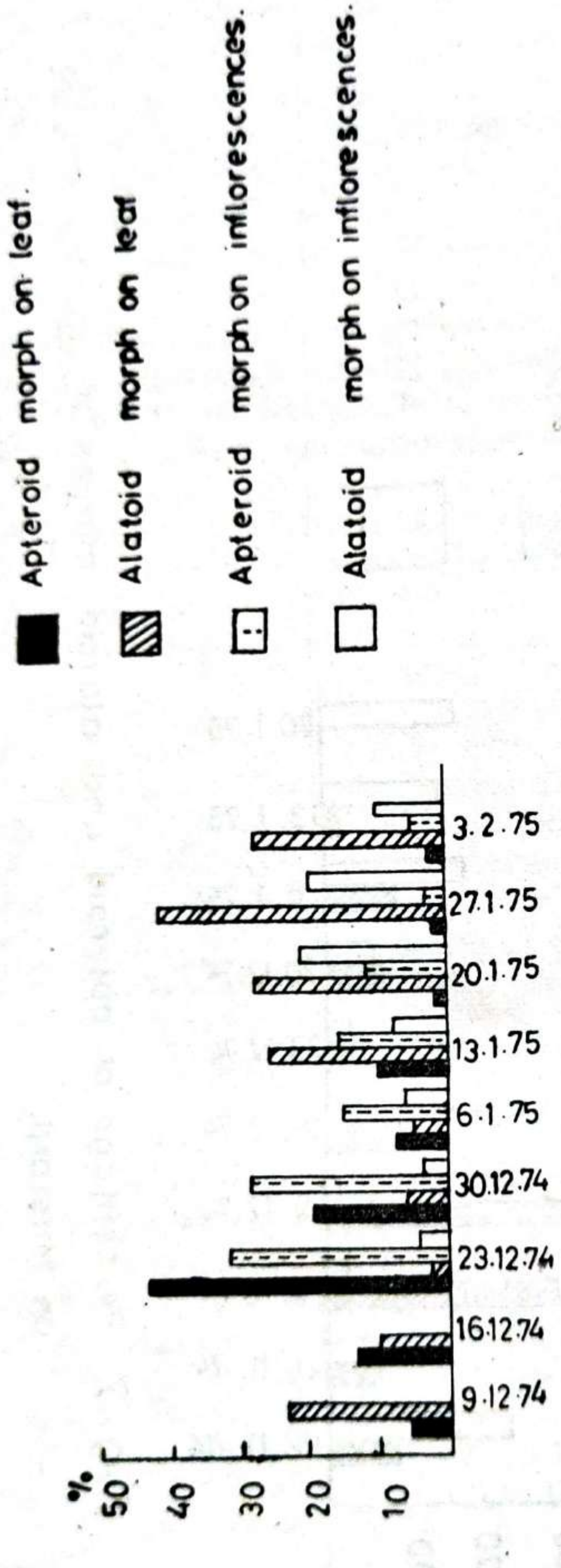

FIG. 3 Percentage of apteroid and alatoid morphs of *Lipaphis erysimi* on Radish.

On radish the percentage of apteroid morphs gradually increased from 5.5 % to 43 % within a fortnight and then decreased to about 2.5 % during the last observation i. e., after 6 weeks from the maximum incidence of this morph. The percentage of the alatoid morphs revealed a somewhat different trend from that of the apteroid morphs. It was found that during the first week of incidence of aphid population on the leaves of this crop, it was 23 % which drastically decreased to only 3 % after two weeks. Again the share of the alatoid morphs showed an increasing trend to reach the maximum of 42 % in the penultimate observation i. e., 5 weeks after the lowest record. It should be noted here that during the first two observations the alatoid morphs comprised alate viviparous females only. This formed the inception of infestation on this crop by the immigrant alates.

Inflorescence in radish started appearing during the third observation Concomitant observation on leaves and inlforescence revealed that the apteroid morphs formed the maximum portion of the population, that is, 31% in the first observation on inflorescence. This gradually decreased to only 6 % during the last observation. The proporiton of alatoid morphs was of more or less reverse order in comparison with the apteroid morphs which to begin with was only 4 % and 21.5 % after 4 weeks and thereafter gradually decreased in the following two weeks to become 10 % in the last observation.

It appears from these observations that the dispersive force in the environment is always there for *L. erysimi* in so far as it relates to cruciferous crops like mustard and radish. However, it should be noted that initiation of population of this aphid on these crops is done by immigrant alates. This speaks for itself as to the cause of relatively high proportion of alatoid morphs during the early phase. The dispersive force gradually increases with the growth of the population which culminates in the widespread distribution of the aphid species on these crops within a very short period. It has been reported that the formation of alatoid morphs is caused by the density of population in the colony. Rattanlal (1957) reported that any condition which leads to the reduction of moisture content of the reproducing form influences production of the alate morphs. In the present experiment analysis of population with regard to the morphs reveals that the population per unit area crossed the critical density within a short time after initiation of infestation by the immigrant alates in large numbers and laying of large number of young ones. Feeding competitiveness of the young ones leads to the dearth of food supply and thus the fluid intake by the individuals is decreased. With further build up of population the condition of food supply deteriorates. The scarcity of food and stress of moisture on the individuals cause increased production of alatoid morphs. This can be visualised from the large share of alatoid morphs in the population in the crops irrespective of crop species or part of the same species of crop infested. During the remaining period of crop season the proportion of alatoid morphs remains not only high but gradually becomes higher. Slight decrease in the proporiton of alatoid morphs during the last two observations was due to the continuous depletion of population by the immigrant alates from the crop during the period of crop maturity. At this stage of the crop sap flow decreased resulting in deficient supply of food and fluid matter to the aphids on them. Coupled with plant condition and effect of feeding by the aphid on the plants, the environmental conditions caused dehydration of the aphids by transpiration as the temperature gradually rose and reletive humidity decreased. It therefore appears that even if other conditions are excluded from consideration, the heavy population, crop maturity and climatic factors together contributed to the moisture stress on the aphids to induce a part of the population on the crops considered here to produce alate morphs. However, at the initial stage of population growth it was more an effect of the density of population than moisture stress that induced formation of alate morphs.

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SEASONAL VARIATION IN THE MORPHOLOGY OF *Aphis gossypii* Glover

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ABSTRACT

The morphology of alate and apterous virginoparae of *Aphis gossypii* Glover reared on *Solanum melongena* during winter, spring and rains of 1974-75 was studied by applying students 't' test. No significant statistical variation is noticed in the measurements of either in the apterae or in the alatae of different seasons. The length of hind leg of spring and winter populations as well as length of body of winter populations of apterae show superior significance over that of the alatae, while in the populations of the rainy season, the length of the fore and hind leg of alatae show superior significance over that of apterae.

INTRODUCTION

Aphis gossypii Glover exhibits great range of morphological variation even on the same host (Behura, 1973). Seasonal variation in morphological structures like the total length of body, antenna, cauda, cornicle and legs have been studied.

MATERIALS AND METHODS

Specimens of adults of alate virginoparae were collected on the egg plant, *Solanum melongena* in Bhubaneswar in July, August, September, October, November and December of 1974 and January and February of 1975. During summer i. e., from March to June due to scarcity of aphids in the field, sufficient specimens of both the morphs were not available for study. Our study therefore represents seasonal variation in Spring (February), Rains (August) and winter (December). Ghovanlou

(1974) has compared morphological variation in *A. gossypii* taking into consideration two host plants viz., cotton and pumpkin.

Bhubaneswar is situated in the eastern coastal area of India about 60 km away from Puri on the sea coast. This is a hilly area devoid of any important river beds in the vicinity. Primarily, four seasons are observed here viz., summer, rains, winter and spring. The summer begins from the middle of March to the middle of June, the rains commence from the middle of June, and continues till the end of September, the heaviest rainfall occurring in August. The winter spreads from the beginning of October to the end of January the intensity of the mild winter being felt from the second fortnight of December to the end of first fortnight of January. Spring follows winter, beginning from February to the middle of March. The principal seasons and their corresponding climatic conditions i. e., temperature and humidity for Bhubaneswar are given in Table 1.

TABLE 1

Temperature and humidity at Bhubaneswar during different seasons (1974-75)

Seasons	Range of temp. in 0°C	Mean temp. in 0°C	Range of humidity in %	Mean humidity in %
Summer (Mid. of March to mid. of June	22.5 — 38.1	30.8	42-90	66 7
Rains (Mid. of June to September)	26 — 35.7	29.6	60-97	78.7
Winter (October to January)	17.5 — 30.0	23.2	51-98	68.7
Spring (February to Mid. of March)	21.6 — 30.0	26.4	51-85	62.0

Specimens were collected in 70% alcohol and Lactic acid. Permanent slides were prepared in balsam. Measurements of 15 apterae and 15 alatae for each month were taken into consideration for biometrical studies.

DATA AND ANALYSIS OF DATA

(a) ***Body*** :

Detailed meteorological data at Bhubaneswar during the period of study are presented in Table 1. Measurements of specimens in different seasons are set in Table 2. The total length of body in apterae in spring, rains and winter are respectively 1.2 2 mm, 1 018 mm and 1.433 mm, but in alatae the figures are respectively 1.075 mm, 1.194 mm and 1.188 mm. Although maximum growth is apparently indicated in winter for both morphs, no significance is indicated in students 't' test. However, apterae show superior significance in winter population over alates in body length (Figs. 1 3).

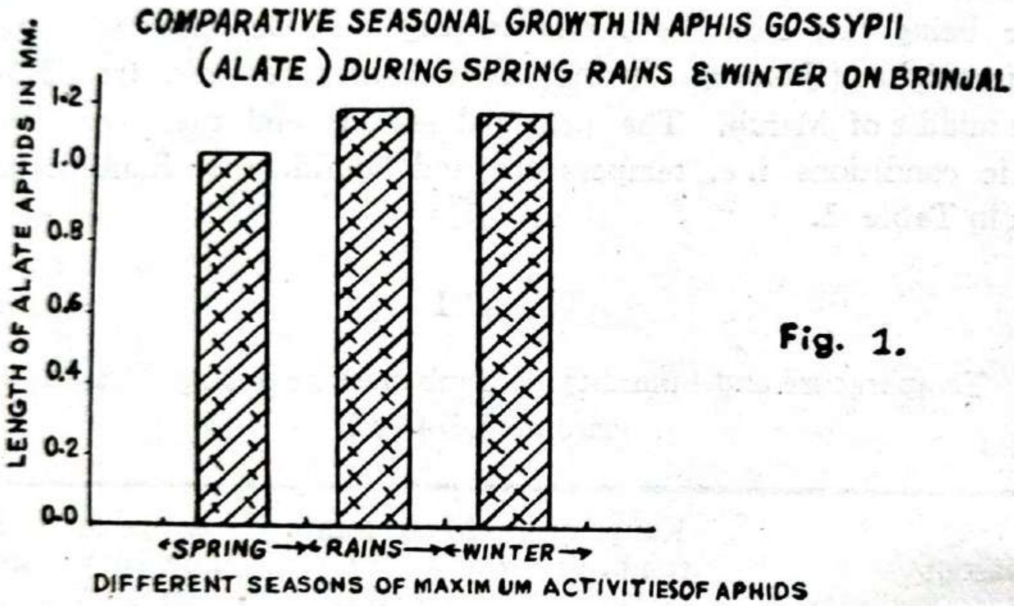

Fig. 1.

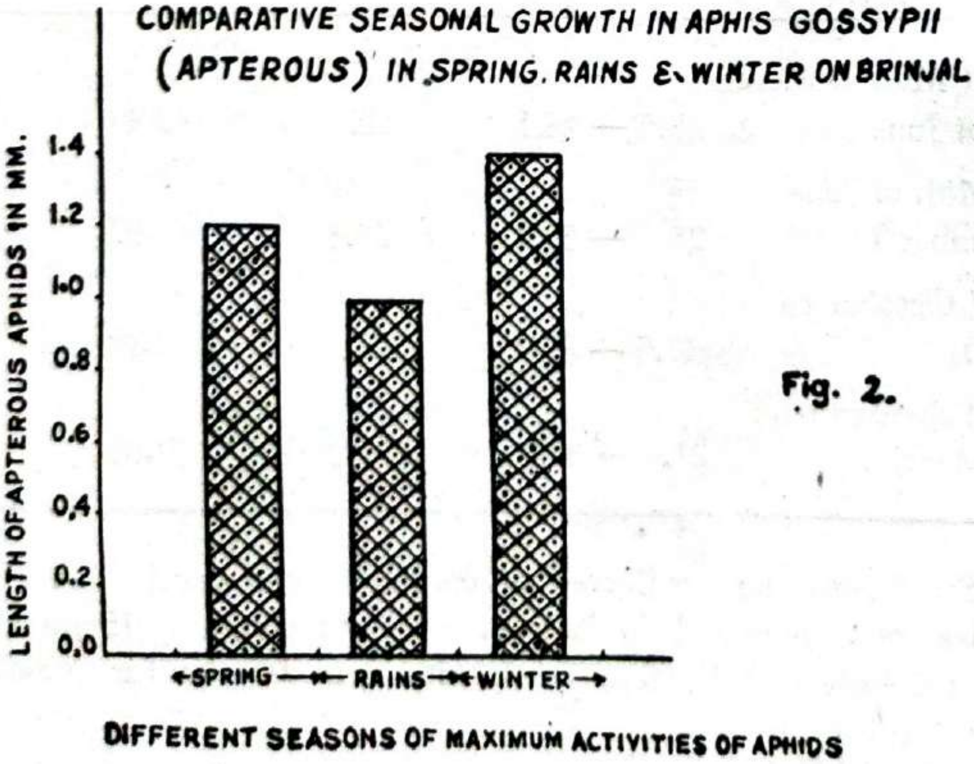

Fig. 2.

Fig. 3.A.

SEASONAL VARIATION IN CORNICLE LENGTH IN *Aphis gossypii* Glov. (APTERAE) REARED ON BRINJAL (*Solanum melongena*) DURING 1974-75

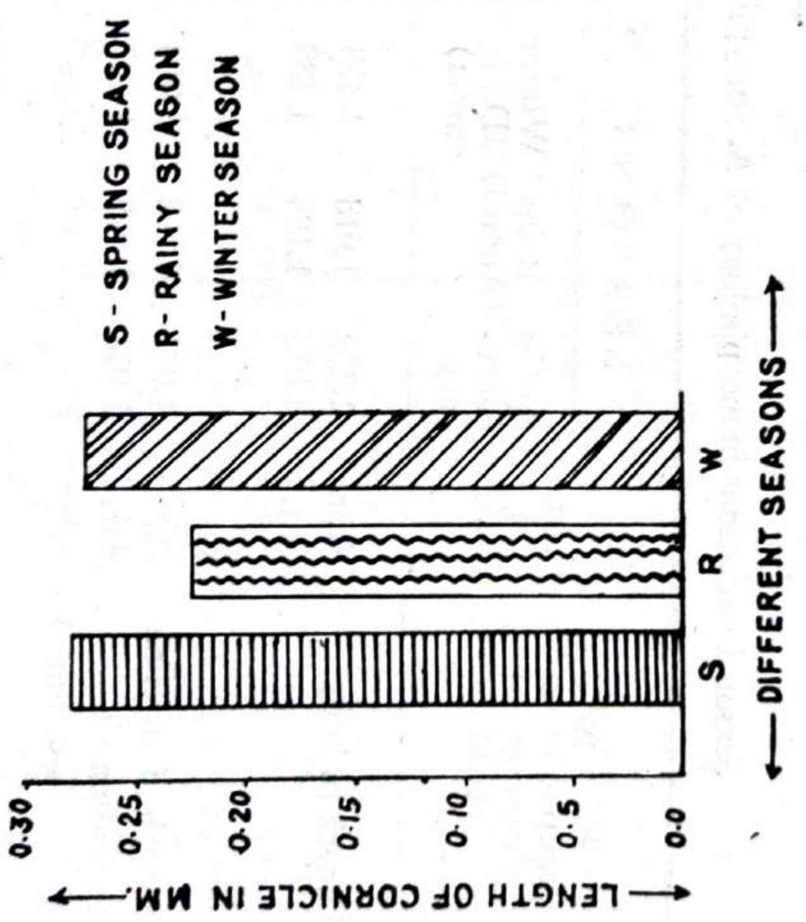

Fig. 3B.

SEASONAL VARIATION IN CORNICLE LENGTH IN *Aphis gossypii* Glov. (ALATAE) REARED ON BRINJAL (*Solanum melongena*) DURING 1974-75

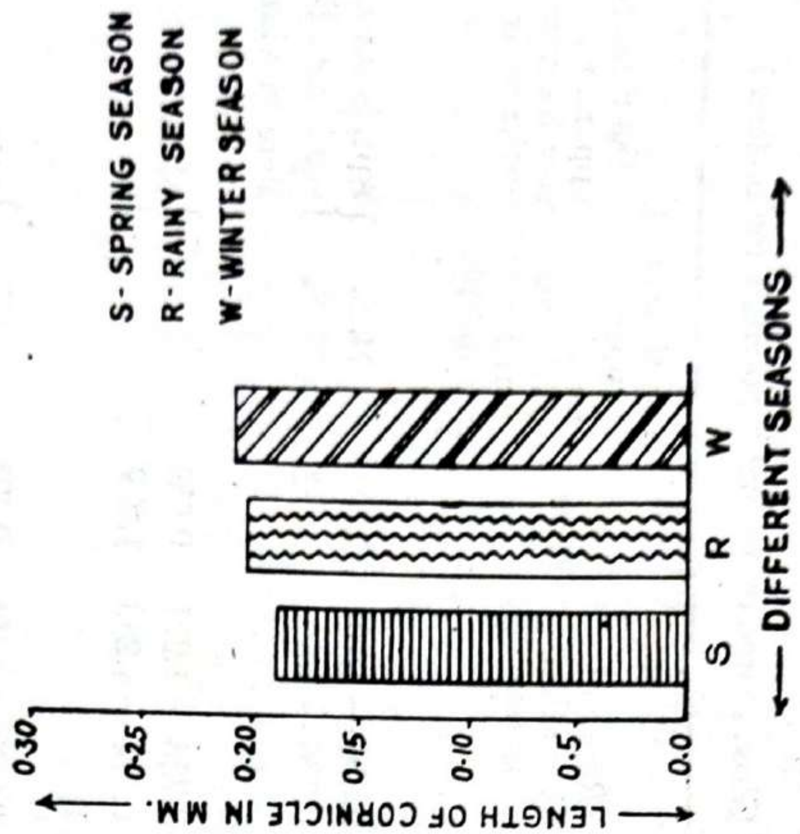

TABLE 2

Seasonal variations in morphology of **A.** gossypii Glov. reared on brinjal (Solanum melongena)

Principal morphological characters of aphid	Forms of aphids	SEASONS Spring (February)	Rains (August)	Winter (December)	Range of variation in mm	Mean	Significance of apparent seasonal growth compared in same morphs	Significance of apparent seasonal growth compared in different morphs
Length of body	Apt.	1.232	1.018	1.433	0.826 — 1.701	1.209	N. S.	Apt. is superiorly significant than alate in winter
	Alt.	1.075	1.194	1.188	0.756 — 1.666	1.193	N. S.	
Length of antenna (including all segments)	Apt.	1.038	0.892	1.058	0.728 — 1.221	0.959		N. S.
	Alt.	1.046	1.028	1.025	0.774 — 1.288	1.029		
Length of cauda	Apt.	0.139	0.104	0.135	0.077 — 0.156	0.125		N. S.
	Alr.	0.098	0 097	0.103	0.070 — C.126	0.097		
Length of cornicle	Apt.	0.280	0.237	0.277	0.137 — 0.336	0.243		N. S.
	Alt.	0.189	0.202	0.208	0.126 — 0.245	0.189		
Foreleg (total) length	Apt.	1.041	0.876	1.062	0.651 — 1 248	0.947		Alates superiorly significant than apterous in rains
	Alt.	1.087	1.166	1.103	0.849 — 1.316	1.114		

Table 2 *(Contd.)*

Seasonal variations in morphology of A. gossypii Glov. rearcd on brinjal (Solanum melongena)

Principal morphological characters of aphid	Forms of aphids	SEASONS			Range of variation in mm	Mean	Significance of apparent seasonal growth compared in same morphs	Significance of apparent seasonal growth compared in different morphs
		Spring (February)	Rains (August)	Winter (December)				
Mid-leg (total) length	Apt.	1.101	0.896	1.131	0.672 — 1.271	1.004		N. S.
	Alt.	1.058	1.137	1.046	0.815 — 1.346	1.073		
Hind-leg (total) length	Apt.	1.429	1.174	1.451	0.798 — 1.680	1.286		Apterae is superiorly significant than alate in spring and winter but alate is superiorly significant during rains.
	Alt.	1.355	1.433	1.349	1.036 — 1.694	1.364		

N. S. = Not significant } at 0.05 P.
S. = Significant

(b) ***Antenna length*** :

The antenna attains maximum growth (1.058 mm) in apterae during winter and in alatae in spring (1.046 mm), yet no significance is indicated in any morph in the different seasons and between the two morphs in any season.

(c) ***Cauda*** :

The cauda attains maximum apparent growth (0.139 mm) in apterae during spring but in alatae during winter and spring (0.098 mm). Comparison of different morphs in the three seasons brings out no significance.

(d) ***Cornicle*** :

In apterae length of cornicle attains maximum in spring (0 280 mm) but in alates it is in rains (0.202 mm). comparison does not indicate statistical significance.

(e) ***Legs*** :

(i) ***Fore leg***—Maximum growth of fore-leg is observed during winter in apterae (1.062 mm) while in alatae the same occurs during rains (1.166) mm. Alate population shows superior significance over apterous forms during rains.

(ii) ***Mid leg***—Maximum apparent growth in length of mid leg is observed in apterae during winter (1.131 mm) but in alatae the same is attained during rains (1.137 mm). No statistical significance is indicated when comparison is made between the two morphs.

(iii) ***Hind leg***—Maximum length of hind leg in apterae is observed during winter (1.451 mm), but in alatae the same is noticed during rains (1.433 mm). 't' test indicates that population during rains shows superior significance in alatae whereas spring and winter populations show superior significance in apterae.

Although winter is believed to be the best season for aphid development in the plains, statistical analysis through students 't' test does not bring out any statistical significance in *Aphis gossypii* on brinjal in different seasons either in the alate or apterous virginoparae. The length of hind leg of spring and winter populations as well as body length of winter populations of apterae show superior significance over that of alatae, while in the population of rainy season, the length of fore and hind leg of alatae show superior significance over that of apterae.

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The Aphids : 60.64

SEASONAL VARIATION IN THE POPULATION OF *Aphis gossypii*, Glover ON BRINJAL, *Solanum melongena*

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ABSTRACT

The population of aphids per single brinjal leaf of 187 sq. cm. in winter was 10.63, in spring 0.12, in summer 0.05 and in rains 4.20. The population was at its peak in November being 22.99 aphids/leaf.

INTRODUCTION

The cotton aphid, *Aphis gossypii* Glover is extremely polyphagous and occurs on a large number of host-plants (Behura, 1963, 1965). It is a 'hot weather' aphid and occurs almost throughout the year in Bhubaneswar on brinjal (*Solanum melongena*).

Ullah (1939-40) recorded that infestation of *A. gossypii* reaches its peak in Delhi from February to April. Raja Rau (1954) reported that the population of this aphid species per average-sized brinjal leaf was highest in July, August and september, the counts being 101.2, 96.2 and 91.0 in number respectively. Uthamaswamy *et al* (1974) made a resistance study in Okra plants to *A. gossypii*. The highest recorded population of aphids per leaf was 32. Ismailov *et al* (1974) stated that in Azerbaidzhan Steppe area the aphid species is comparatively more populous on cotton. The population of *A. gossypii* on brinjal in different seasons form the subject of the present investigation.

MATERIALS AND METHODS

Lay-out of plot :

An experimental field plot was laid out measuring 13.8 m. in length and 10.7 m. in breadth in the Central Farm (O. U. A. T.) in north-south direction. The field was levelled, divided into 3 rows (or replications viz., Rep-I, Rep-II, and Rep-III) comprising 4 sub-plots in a row. Altogether there were 12 sub-plots each measuring 3 m × 3 m. Planting of brinjal seedlings were done four times in a year i. e., on the dates June 20, August 6, September 11 and November 7, 1974 so that a gap of 30-45 days was maintained in between two consequitive plantings. On each occasion of planting 3 sub-plots were selcted at random from 3 replications. Four such sets of plantings of brinjal seedlings (about a month old) were done during the period 20-6-74 to 7-11-74. Fertilizers like Nitrogen, phosphorous and potash @ 30 Kg : 20 Kg :, 20 Kg/ acre were added to soil in the experimental plot with 2-3 cart-loads of cowdung manure before planting. The seeds of brinjal were separately sown in a nursery bed. When the seedlings were a month or 30 days old with 2-3 leaves they were transplanted in each sub-plot. As such 75 seedlings were planted in 5 sub-plots, 25 plants in each sub-plot with row to row gap of 30 cm and plant to plant gap of 45 cm. Care was taken to irrigate the field properly and timely addition of chemical fertilizers like C. A. N. (Calcium-Ammonium-Nitrate) was made when the plants were about 1 ft (30 cm) tall. Proper cleaning of the field and complete restriction of use of insecticide sprays were strictly observed throughout the entire period of experiment. The planted sub-plots were labelled with dates of plantings. Of the 19 varieties of brinjal grown in Orissa (Panda, Mohapatra and Sahu, 1971), Pusa purple cluster variety was selected for this experiment, as this varietv is a popular one and is cultivated around the year.

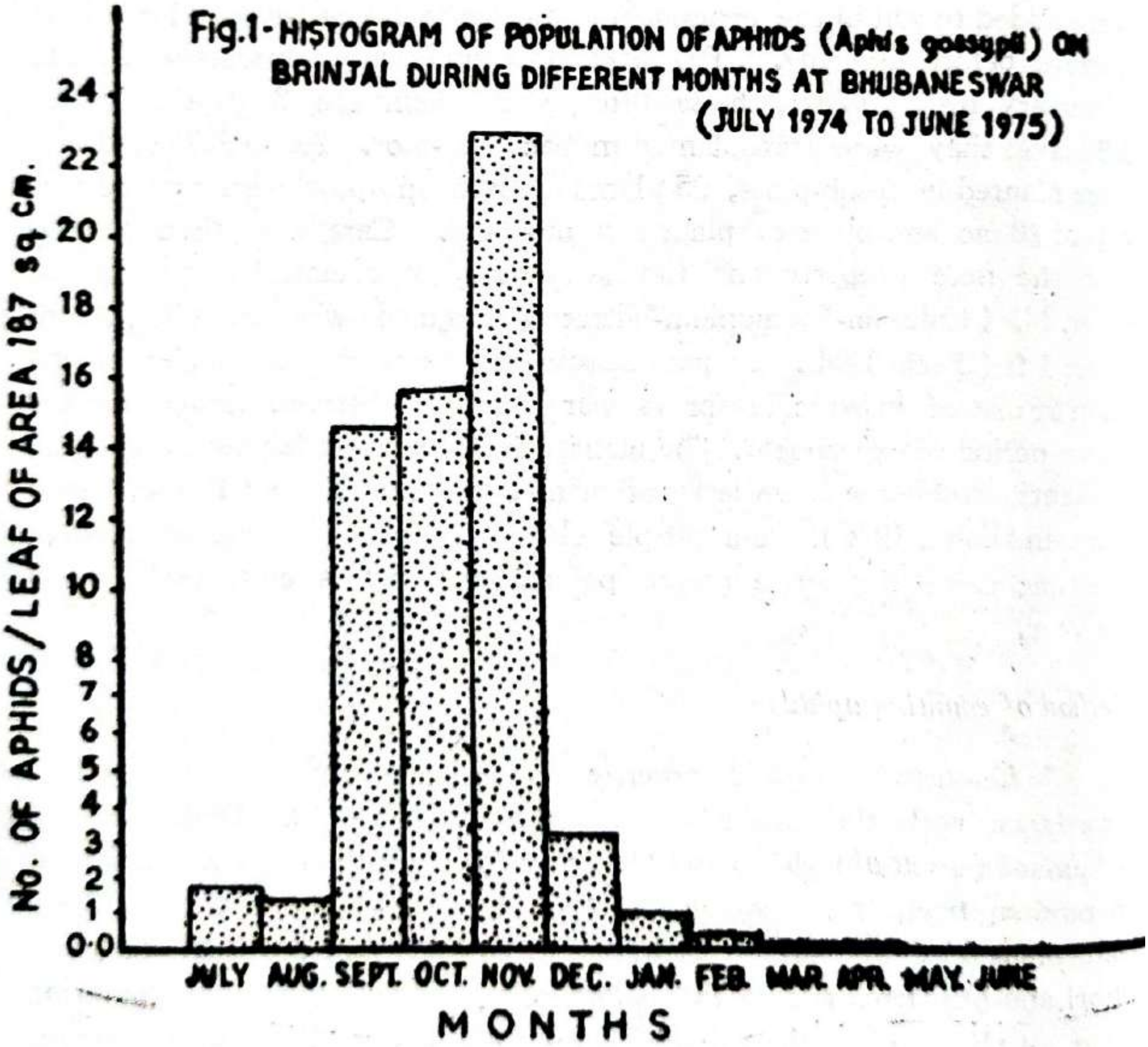
Method of counting aphids :

Counting of aphid populations on brinjal plants was done in accordance with the methods followed by workers like Dash (1974), Uthamaswamy *et al* (1974) and Khan (1976). Five plants were selected at random from 3 replications for taking weekly observations From each plant 3 leaves were selcted, one from top whorl, one from bottom whorl and one from the middle whorl of the plant. Likewise population count of all stages of the aphid species (viz. adult alate, adult apterous and nymphs) was done on 45 leaves comprising 15 plants split into 3 rows in the experimental plot. The observations were recorded from July 1974 to June, 1975. The mean number of aphids was calculated on a single average-sized brinjal leaf having a surface area of 187 sq. cm. Likewise mean monthly aphid population was established by taking into consideration observation recorded in the four weeks of the month at an interval of seven days. The brinjal plants remained alive for about a year and planting of seedlings was done on 4 occasions as a result of which no difficulty was experienced in maintaining plants throughout the year for recording observations.

DATA AND ANALYSIS OF DATA

The data are presented in Fig. 1. The months of September through November showed the highest aphid infestation, the count being 14.62, 15.48 and 22.99 respectively, on a average leaf of 187 sq. cm., the month of November showing the largest number 22.99, during

Fig.1-HISTOGRAM OF POPULATION OF APHIDS (*Aphis gossypii*) ON BRINJAL DURING DIFFERENT MONTHS AT BHUBANESWAR (JULY 1974 TO JUNE 1975)



which the mean temperature showed 24.2 °C, and 66% RH with 4 rainy days. The mean wind velocity recorded 5.4 km/hr and mean sunshine 8.4 hrs. In May-June the temperature stood at 31°-32° C and no aphid was noticed on the leaves of brinjal plants. From December the population declined showing per single leaf 3.21 in December, 0.85 in January, 0.15 in February, 0.10 in March, 0.12 in April and 0 in may and June and 1.45 in July.

When considered seasonwise aphid population on a single average-sized brinjal leaf was 0.05 in summer, 4.20 in rains, 10.63 in winter and 0.12 in spring. The highest activities of *A. gossypii* were recorded in the last part of the rains and early part of winter. The suitability of aphids for multiplication in order of seasons is winter, rains, spring and summer.

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The Aphids : 65-74

BIOMETRICAL STUDIES OF THE COTTON APHID, *APHIS GOSSYPII* GLOVER WITH REGARD TO THREE DIFFERENT HOST-PLANTS

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ABSTRACT

Biometrical data in respect of apterous viviparous parthenogenetic forms of *Aphis gosaypii* Glover collected on three different host-plants viz., *Tridax procumbens*, *Solanum melongena* and *Helianthus annus* have been statistically analysed. Among the three host plantrs *S. melongena* proved to be most suitable for the growth of different morphological characters of apterous forms in comparison with *T. procumbens* and *H. annuus.* Ratios of taxonomically important morphological characters have been worked out for the three populations and it is found that length of cornicle/length of cauda in apterae shows remarkable variation.

INTRODUCTION

In an earlier paper Behura *et al* (1975) studied the biometry of the common polyphagous cotton aphid, *Aphis gossypii* Glover with regard to three different host-plants viz., *Tridax procumbens*, *Cocculus villosus* and *Psidium guajava*. In the present investigation similar studies have been undertaken on the aphid species with regard to another set of three host-plants viz., *T. procumbens*, *Solanum melongena* and *Helianthus annuus.*

MATERIALS AND METHODS

Adult apterous specimens of *A. gossypii* were collected from *Tridax procumbens*, *Solanum melongena* and *Helianthus annuus* during February 1977 at Bhubaneswar and the required measurements were taken as described earlier by Behura *et al* (1976).

At a time the measurements of any particular morphological character of *A. gossypii* collected from two different host-plants were subjected to 't' test.

From the significant characters the superiorly significant characters were deduced. The plant which showed superiorly significant result with regard to most of the morphological characters of the aphid species was regarded as the most suitable one.

DATA AND ANALYSIS OF DATA

The measurements of different morphological characters of the aphid populations on the three different host-plants, along with their coefficient of variation are presented in Table 1. The calculated value of 't' for the three sets of host-plants are set in Table 2. Ratios of measurements of taxonomically important characters of *A. gossypii* on the three host plants are given in Table 3. The significantly superior characters of apterous forms of *A. gossypii* in relation to the corresponding ones on the three different hostplants are given in Table 4.

Studies of biometry of apterous forms of *A. gossypii* belonging to three different populations and collected on three different host plants, viz., *T. procumbens, S. melongena* and *H. annuus* show that the host plant plays an important role in influencing the size of different morphological characters of the aphid species and that *S. melongena* is undoubtedly its most suitable host plant among the three plants.

If a gradation of host plants under study is made for apterae of *A. gossypii* on the basis of host suitability, the result stands thus—

S. melongena > *T. procumbens* > *H. annuus.*

Ratios of characters of taxonomic importance were worked out for all the three populations of *A. gossypii* on the three different host-plants and compared among themselves. It is observed that length of cornicle/length of cauda in apterae show remarkable variation.

It is interesting to note that no superiorly significant characters are found in apterous populations of *A. gossypii* on *Helianthus annuus* indicating thereby that it may be a secondary host.

TABLE 1

Measurements (in mm) of morphological characters of apterous forms of the *Aphis gossypii* Glover collected on *Tridax procumbens*, *Solanum melongena* and *Helianthus annuus* at Bhubaneswar during February 1977.

No. of obs.	Characters (length)	*Tridax procumbens* Mean in mm ± S.D.	*Tridax procumbens* C.V. in %	*Solanum melongena* Mean in mm ± S.D.	*Solanum melongena* C.V. in %	*Helianthus annuus* Mean in mm ± S.D.	*Helianthus annuus* C.V. in %
1.	Length of body	1.043 ± 0.162	11.33	1.482 ± 0.1496	10.1	1.131 ± 0.099	8.75
2.	Breadth of body	0.767 ± 0.0939	12.25	0.793 ± 0.085	10.72	0.637 ± 0.06	9.42
3.	Breadth of head	0.299 ± 0.0193	6.46	0.299 ± 0.0307	10.26	0.268 ± 0.0037	5.89
4.	Length of rostrum Seg. I+II	0.182 ± 0.0266	14.65	0.221 ± 0.0231	10.45	0.182 ± 0.0204	11.22
5.	Length of rostrum III	0.065 ± 0.0059	9.17	0.065 ± 0.0066	10.25	0.052	—
6.	Length of rostrum IV	0.091 ± 0.0089	9.83	0.091 ± 0.0078	8.67	0.078 ± 0.0078	10.11
7.	Total length of rostrum	0.338 ± 0.0328	9. 7	0.377 ± 0.026	6.89	0.312 ± 0.0206	6.62
8.	Length of antenna Seg. I	0.039 ± 0.0107	27.57	0.052 ± 0.0051	9.73	0.039 ± 0.0089	22.13
9.	,, ,, II	0.039 ± 0.0103	26.48	0.052 ± 0.0059	11.47	0.039	—
10.	,, ,, III	0.195 ± 0.0284	14.58	0.1234 ± 0.0438	18.73	0.159 ± 0.0163	10.47
11.	,, ,, IV	0.143 ± 0.0173	12.16	0.156 ± 0.0244	15.64	0.104 ± 0.0133	12.82
12.	,, ,, V	0.13 ± 0.0139	10.76	0.156 ± 0.0202	12.96	0.104 ± 0.0107	10.33

Table 1—(Contd.)

Measurements (in mm) of morphological characters of apterous forms of the *Aphis gossypii* Glover collected on *Tridax procumbens*, *Solanum melongena* and *Helianthus annuus* at Bhubaneswar during February 1977.

No. of obs.	Characters (length)	*Tridax procumbens* Mean in mm ± S.D.	*Tridax procumbens* C.V. in %	*Solanum melongena* Mean in mm ± S.D.	*Solanum melongena* C.V. in %	*Helianthus annuus* Mean in mm ± S.D.	*Helianthus annuus* C.V. in %
13.	Length of antenna Seg. VI (base)	0.078 ± 0.0119	15.29	0.091 ± 0.0126	13.9	0.078 ± 0.0089	11.46
14.	,, ,, VI (flag.)	0.234 ± 0.0315	13.48	0.273 ± 0.0176	6.46	0.182 ± 0.0217	11.92
15.	Total length of antennae	0.975 ± 0.1107	11.35	0.014 ± 0.0995	9.81	0.728 ± 0.0318	4.37
16.	Length of foreleg : coxa	0.065 ± 0.0059	9.17	0.065 ± 0.0006	10.25	0.035 ± 0.0051	7.94
17.	,, ,, trochanter	0.052 ± 0.0078	15.17	0.052 ± 0.0078	15.17	0.059 ± 0.0029	5.73
18.	,, ,, femur	0.247 ± 0.0234	9.5	0.273 ± 0.0377	13.81	0.221 ± 0.0119	5.39
19.	,, ,, tibia	0.492 ± 0.045	10.18	0.481 ± 0.0619	12.87	0.351 ± 0.02	5.69
20.	,, ,, tarsus I	—	—	0.013 ± 0.0059	45.88	0.013	—
21.	,, ,, tarsus II	0.065 ± 0.0051	7.94	0.965	—	0.065 ± 0.0042	6.48
22.	,, ,, claw	—	—	0.013	—	0.13	—
23.	Total length of foreleg	0.897 ± 0.0882	9.82	0.962 ± 0.1075	11.17	0.776 ± 0.312	4.07
24.	Length of mid leg coxa	0.065 ± 0.0103	15.89	0.065 ± 0.0119	11.35	0.065 ± 0.0059	9.17

Table 1—(*Contd.*)

Measurements (in mm) of morphological characters of apterous forms of the ***Aphis gossypii*** Glover collected on ***Tridax procumbens***, ***Solanum melongena*** and ***Helianthus annuus*** at Bhubaneswar during February 1977.

No. of obs.	Characters (length)	*Tridax procumbens* Mean in mm ± S.D.	*Tridax procumbens* C.V. in %	*Solanum melongena* Mean in mm ± S.D.	*Solanum melongena* C.V. in %	*Helianthus annuus* Mean in mm ± S.D.	*Helianthus annuus* C.V. in %
25.	Length of mid leg trochanter	0.0526 ± 0.0051	9.93	0.052 ± 0.0103	19.86	0.052 ± 0.0042	8.1
26.	,, ,, femur	0.2561 ± 0.0318	12.89	0.286 ± 0.0299	10.47	0.221 ± 0.0152	6.88
27.	,, ,, tibia	0.4784 ± 0.0302	6.46	0.52 ± 0.0692	13.31	0.39 ± 0.0173	4.44
28.	,, ,, tarsus I	0.0062	—	0.013 ± 0.0042	32.43	0.013	—
29.	,, ,, tarsus II	0.0663 ± 0.0073	11.23	0.065	—	0.065	—
30.	,, ,, claw	0.0062	—	0.013	—	0.013	—
31.	Total length of midleg	0.897 ± 0.0184	8.68	1.027 ± 0.1068	10.4	0.793 ± 0.0206	—
32.	Length of hindleg : coxa	0.078 ± 0.0089	11.64	0.078 ± 0.0103	13.24	0.065 ± 0.0051	7.94
33.	,, ,, trochanter	0.052 ± 0.0066	12.82	0.065 ± 0.0066	10.15	0.052	—
34.	,, ,, femur	0.025 ± 0.0406	12.51	0.364 ± 0.0467	12.85	0.299 ± 0.0098	3.3
35.	,, ,, tibia	0.607 ± 0.0734	11.52	0.702 ± 0.0789	11.24	0.546 ± 0.0143	2.61
36.	,, ,, tarsus I	0.0062	9.17	0.013 ± 0.0084	4.88	—	—

Table 1—(Contd.)

Measurements (in mm) of morphological characters of apterous forms of the *Aphis gossypii* Glover collected on *Tridax procumbens*, *Solanum melongena* and *Helianthus annuus* at Bhubaneswar during February 1977.

No. of obs.	Characters (length)	*Tridax procumbens* Mean in mm ± S.D.	C.V. in %	*Solanum melongena* Mean in mm ± S.D.	C.V. in %	*Helianthus annuus* Mean in mm ± S.D.	C.V. in %
37.	Length of hindleg tarsus II	0.065 ± 0.0059	—	0.065 ± 0.0042	6.48	—	22.93
38.	" " claw	0.0062	—	0.013	—	—	—
39.	Total length of hindleg	0.209 ± 0.1177	9.73	1.313 ± 0.13	9.9	1.079 ± 0.0487	4.51
40.	Length of cauda	0.117 ± 0.0115	9.87	0.117 ± 0.02	17.9	0.104 ± 0.0133	12.82
41.	Length of cornicle	0.273 ± 0.0314	11.5	0.247 ± 0.0448	18.15	0.169 ± 0.0247	14.05

TABLE 2

Significant test of morphological characters of adult apterous virginoparae of ***Aphis gossypii*** Glover, collected on ***Tridax procumbens***, ***Solanum melongena*** and ***Helianthus annuus***

No. of obs.	Characters	Calculated value of 't' at 5% probability and 38 degree of freedom		
		T. procumbens* and *S. melongena	***T. procumbens* and *H. annuus***	***S. melongena* and *H. annuus***
1.	Body length	1.054	7.04	8.7469*
2.	Breadth of body	0.9174	5.2137*	6.7027*
3.	Breadth of head	—	2.2665*	1.6597
4.	Length of rostrum Seg I+II	4.9431	10.3788*	5.655*
5.	Length of rostrum Seg III	—	9.7656*	8.7412*
6.	Length of rostrum Seg IV	—	4.8756*	0.0005
7.	Total length of rostrum	4.1666*	2.9994*	1.7507
8.	Length of antenna Seg I	4.8756*	—	5.6369*
9.	,, ,, II	4.8756*	—	9.7656*
10.	,, ,, III	3.3381*	5.3172*	4.972*
11.	,, ,, IV	1.9402	7.9596*	1.3612*
12.	,, ,, V	4.7292*	6.5919*	5.0774*
13.	,, ,, VI base	3.3456*	—	3.7537*
14.	,, ,, VI flag	4.8239*	6.0707*	14.5499*
15.	Total length of antenna	1.0765	9.5857*	10.4448*
16.	Length of fore leg coxa	—	—	—
17.	,, ,, trochanter	—	—	—
18.	,, ,, femur	2.6167*	4.4159*	5.878*
19.	,, ,, tibia	2.2782*	8.2595*	8.9357*
20.	,, ,, tarsus I	—	—	—
21.	,, ,, tarsus II	—	—	—
22.	,, ,, claw	—	—	—

Table 2—(*Contd.*)

Significant test of morphological characters of adult apterous virginoparae of *Aphis gossypii* Glover, collected on *Tridax procumbens*, *Solanum melongena* and *Helianthus annuus*.

No. of obs.	Characters	Calculated value of 't' at 5% probability and 38 degree of freedom		
		T. procumbens and *S. melongena*	*T. procumbens* and *H. annuus*	*S. melongena* and *H. annuus*
23.	Total length of foreleg	2.0899*	6.2111*	7.7873*
24.	Length of midleg coxa	—	—	—
25.	,, ,, trochanter	—	—	—
26.	,, ,, femur	3.9888*	3.2954*	8.649*
27.	,, ,, tibia	3.0676*	9.9933*	8.1439*
28.	Length of midleg tarsus I	—	—	—
29.	,, ,, tarsus II	—	—	—
30.	,, ,, claw	—	—	—
31.	Total length of midleg	2.5852*	8.2146*	9.6143*
32.	Length of hindleg coxa	—	5.6369*	5.0403*
33.	,, ,, trochanter	0.0006	—	8.7412*
34.	,, ,, femur	2.8137*	2.7777*	6.6805*
35.	,, ,, tibia	2.6971*	5.4411*	8.7*
36.	,, ,, tarsus I	—	—	—
37.	,, ,, tarsus II	—	—	—
38.	,, ,, claw	—	—	—
39.	Total length of hindleg	2.6512*	4.5632*	7.5342*
40.	Length of cauda	—	3.2959*	2.4183*
41.	Length of cornicle	2.1238*	11.6262*	6.8104*

* Significant

TABLE 3

Mean ratios of measurements of taxonomically important characters of apterous viviparous parthenogenetic forms of *Aphis gossypii* Glover on three different host-plants.

No. of obs.	Characters	*T. procumbens*	*S. melongena*	*H. annuus*
1.	Length of antennal Seg. IV / ant. Seg. III	0.733	0.666	0.666
2.	Length of ant. Seg. V / ant. Seg. III	0.666	0.666	0.666
3.	Length of ant. Seg. VI base / ant. Seg. III	0.4	0.388	0.5
4.	Length of ant. Seg. VI (flag) / ant. Seg. III	1.2	1.166	1.083
5.	Length of cornicle / ant. Seg. III	1.4	1.055	1.083
6.	Length of cauda / ant. Seg. III	0.6	0.5	0.666
7.	Length of antenna / Length of body	0.681	0.684	0.643
8.	Length cornicle / Legth of cauda	2.333	2.111	1.625
9.	Length of cornicle / Length of body	0.19	0.166	0.149

TABLE 4

Statement of most significant characters of apterous viviparous parthenogenetic forms of *Aphis gossypii* Glover collected on three different host-plants.

No. of obs.	*Tridax procumbens*	*Solanum melengena*	*Helianthus annu*
	1. Length of body	1. Breadth of body	
	2. Breadth of head	2. Rostral Seg I + II	
	3. Rostral Seg III	3. Ant. Seg I	
	4. Rostral Seg IV	4. Ant. Seg II	
	5. Total length of rostrum	5. Ant. Seg III	
	6. Length of foreleg fumur	6. Ant. Seg IV	
	7. Length of cauda	7. Ant. Seg V	
	8. Length of cornicle	8. Ant. Seg VI (base)	
		9. Ant. Seg VI (flag)	
		10. Total length af antenna	
		11. Length of foreleg : tibia	
		12. Total length of foreleg	
		13. Length of midleg : femur	
		14. Length of midleg tibia	
		15. Total length of midleg	
		16. Length of hindleg : coxa	
		17. Length of hindleg trochanter	
		18. Total length of hindleg	

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The Aphids : 75-83

II. ZOOGEOGRAPHY

APHIDOIDEA OF THE INDIAN REGION

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ABSTRACT

A high percentage of endemism is noted in the aphid fauna of India varying between 33% (Aphidinae) and 90% (Anoeciinae). About 20% of the genera and 50% of the total species are endemic.

INTRODUCTION

Aphidoidea of the Indian region presents some distinctive features. A total of nearly seven hundred species belonging to 208 genera are now known from the region. Considering the known world fauna, the Indian region is having more than 10% of the species and nearly 40% of the known genera. For a predominantly tropical country in the Oriental region, this figure appears to be rather surprisingly high but, an analysis of available records indicates that the major faunal elements are represented in the temperate areas of the Himalayas and its entire foot hills, extending from Kashmir Himalaya to Eastern Himalaya, through Punjab, Kumaon and Nepal, the great plains, central high lands, and peninsular plateaus offer very minor portion of the total fauna. Aphids being an obligatory group of phytophagous insects, the great floral diversity in the Northern mountains could be regarded as the major decisive factor in the distribution of the Indian aphid fauna.

Out of the three families of Aphidoidea, Phylloxeridae is unknown from the region. An account of Aphididae and Adelgidae is given in the present paper.

SUBFAMILY LACHNINAE

Three tribes Cinarini, Lachnini and Tramini are represented by 14 genera. Of these, *Cinara* Curtis represents the largest genus in so far as the number of species are concerned. Out of these 14 genera, three genera, *Indocinara* Ghosh *et. al.*, *Pseudessigella* Hille Ris Lambers and *Pyrolachnus* Hille Ris Lambers and Basu, are endemic in origin. A total of 36 species and sub-species is known, of which 24 species and 2 sub-species are endemic in origin; of the rest, 6 species are known from Eastern Palaearctic region and the rest from wider areas of Palaearctic region except *thunbergii* Wilson. The host plants of Indian Lachnids include Coniferae, Compositae, Fagaceae, Rosaceae, Salicaceae etc.

SUBFAMILY CHAITOPHORINAE

Two tribes, Chaitophorini and Siphini are represented by 4 exotic genera of which only one genus *Sipha* Passerini and a single species *S. R. maydis* is known under Siphini. Both *Chaitophorus* Koch and *Periphyllus* van der Hoeven are well represented, having 10 species and 7 species respectively. Out of a total of 20 species under the subfamily, 14 species are endemic in origin and of the remaining species, 5 species are Western Palaearctic in origin and one is known only from the Eastern Palaearctic region. The host plants of Chaitophorinae in the region include Aceraceae, Hippocastaneaceae, Salicaceae, Graminae etc.

SUBFAMILY DREPANOSIPHINAE

Two tribes Drepanosiphini and Saltusaphidini are represented by 32 genera and 44 species, of which *Saltusaphis scripus* Theobald is the only species known grom Saltusaphidini. Most of the genera are represented by one or two species, except *Tinocallis* Matsumura which has 4 different species. Nine genera and all but eight species are endemic in origin, while almost all of the rest are known from Eastern Palaearctic region, except *Saltusaphis scripus* Theobald. The host plants of Drepanosiphinae include Graminae, Betulaceae, Fagaceae, Leguminosae, Juglandaceae, Rosaceae and bamboos. *Alnus*, *Betula*, *Prunus*, *Quercus* act as the most favoured host plant genera in the region.

SUBFAMILY PTEROCOMMATINAE

Only one species of *Pterocomma* from *Populus* is known under the subfamily. Two predominant genera *Plocamaphis* Oestund and

Pterocomma Buckton of this subfamily are Nearctic and Palaearctic in distribution but some spacies are known from Eastern Palaearctic areas in Japan.

SUBFAMILY APHIDINAE

About 100 genera are represented under this subfamily in the Indian region of which 15 are endemic in origin. A total of more than 431 species are now known to occur, representing more than 50% of the total aphid fauna of the region and a large number of these (172) are endemic in origin; most of the remaining genera and species are known from Palaearctic region, but some genera like *Akkaia* Takahashi, *Eomyzus* Takahashi, *Eumyzus* Takahashi, *Matsumuraja* Schumacher, *Metaphorodon* Takahashi are typically Eastern Palaearctic, while others like *Micromyzus* van der Goot, *Myzaphis* van der Goot, etc., are Oriental in origin. Numerous host plants belonging to Graminae and dicots have been recorded in the region, specially for a number of well-known polyphagous species of Aphidinae.

SUBFAMILY GREENIDEINAE

Two tribes, Greenideini and Cervaphidini are represented by 12 genera (6 + 6) and by a total of 77 species, majority of which belong to Greenideini. As the entire group is restricted to South East Asian region, most of the species, till proper surveys were made in the region from 1960's onwards, were known from Japan, China, Formosa, Thailand and Malaya. The species-group in the Indian region shows a very high degree of endemicity (nearly 75%), while most of genera excepting two, are exotic. Most species are known form Eastern Himalaya, infesting plants of Fagaceae, besides other dicot trees. Some of the genera e. g., *Anomalosiphum* Takahashi, *Allotrichosiphum* Takahashi which were so for monotypic, are represented in the region by a second species which is endemic in origin.

SUBFAMILY ANOECIINAE

Two tribes, Aiceonini and Anoeciini are represented by 3 genera, two of which are Eastern Palaearctic in origin, while the third *Anoecia* Baker is widely distributed over Nearctic, Palaearctic and other regions. A total of 10 species, 9 of which are endemic in origin, are known from the region; majority of the species of *Aiceona* are known from Lauraceae while those of *Anoecia* are known from roots of Graminae,

SUBFAMILY HORMAPHIDINAE

The tribe Oregmini is represented by 9 genera of which two viz., *Pseudoastegypteryx* Ghosh, Pal and Raychaudhuri, and *Pseudoregma* Buckton are endemic in origin and the tribe Cerataphidini is represented by 12 genera of which two viz., *Indonipponaphis* Ghosh and Raychaudhuri and *Homipodaphis* David *et al* are endemic; most of the other genera in both the tribes are well-known in the Eastern Palaearctic region. A total of 39 species is known of which 18 are endemic and are mostly known from Eastern Himalayan region. Some genera like *Euthoracaphis* Takahashi and *Nipponaphis* Pergande are represented only by endemic species. In general, members of Hormaphidinae are mostly known from bamboos and plants of Fagaceae, Lauraceae etc. It may be noted that primary hosts (e. g. *Styrax*, *Distylium*) of many species which are heteroecious elsewhere are unknown in the region and the species appear to lead anholocyclic monoecious cycle in the region.

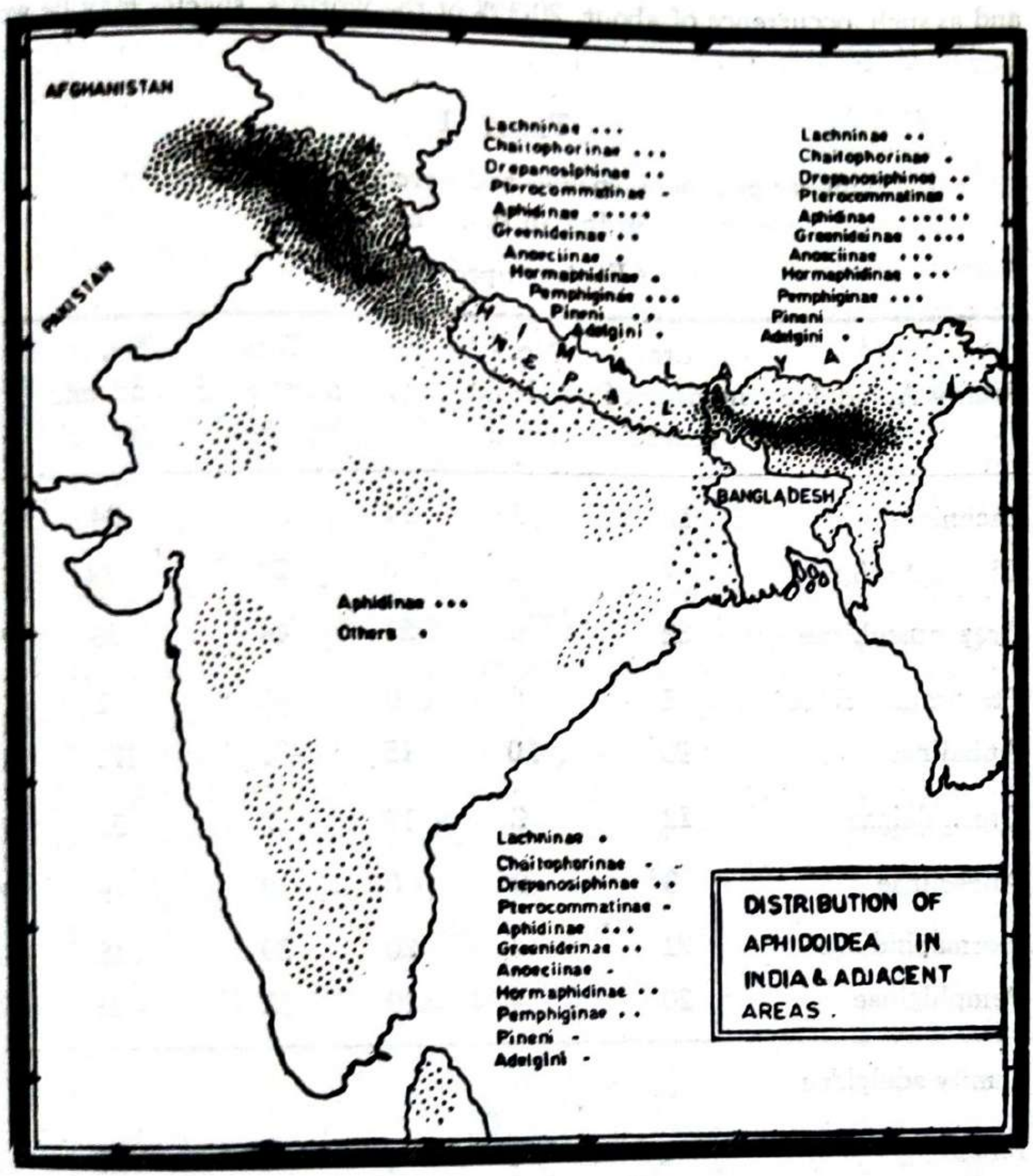
SUBFAMILY PEMPHIGINAE

Three tribes viz., Pemphigini, Eriosomatini and Fordini are represented by 20 genera and 52 species of which 4 genera and 31 species are endemic in origin. The species group include some of the otherwise widely known species of the genera *Asiphonella* Passerini, *Eriosoma* Leach, *Geoica* Hart, *Pemphigus* Hartig, *Tetraneura* Hartig, etc. Members of Pemphiginae are known to alternate between *Populus, Ulmus, Pistacia* and roots of dicots, angiosperms, conifers and Graminae; in the region, however, most of the species are known either from the galls of first named group of plants or from roots of second named group of plants indicating that at least some of the species have switched over to anholocyclic monoecious cycle, as has been observed in Hormaphidinae.

FAMILY ADELGIDAE

The family Adelgidae is represented by 3 genera only viz., *Adelges* Vallot, *Aphrastasia* Börner (now regarded as a subgenus of *Adelgas* by Eastop & Hille Ris Lambers, 1976) and *Pineus* Shimer 1869. Members of Adelgidae are known to be taxonomically a difficult group. Primary host of heteroecious adelgids, is *Picea* and secondary hosts include only Coniferae. Two species, *Adelges* (*Dreyfusia*) *joshi* Schneider—Orelli and Schneider and *Adelges (D) knuchelli* Schneider—Orelli & Schneider are known from *Abies* in the Northwestern Himalaya; *Aphrastisea tuniticta* Prey is represented in collections of British Museum from Indian region from

Tsuga brmunoniana; two species, ***Pinus laevis*** (Maskell) from ***Pinus roxburghi***, and ***Pineus pini*** (Macquart) from ***Pinus .excelsa*** have been recorded from Nepal, while natural enemies of an undetermined species of ***Pineus*** infesting pines, was observed by Chacko (1973) in Meghalaya in Eastern India.



DISCUSSION

Some salient features become apparent from the foregoing study on aphids of the Indian region. In some groups like Pterocommatinae, the fauna appears to be very insignificant in relation to world fauna

(only 0.2%) while in others it may be as high as 66% as in Greenideinae, which is however a South East Asian Group. However, in the subfamilies which have a much wider distribution range, like Lachninae (10%), Chaitophorinae (14%), Drepanosiphinae (10%), Aphidinae (17%) and Pemphiginae (15%) the representation appears to be fairly on the higher side (Table 1). In subfamilies Anoeciinae and Hormaphidinae, many genera are predominantly Eastern Palaearctic in origin and distribution and as such occurrence of about 20-25% of the world's species may be well explained (Table 2).

TABLE 1

Number of genera, species and percentage of endemism in Indian Aphidoidea

(Figures upto 1978)

Family Aphididae	Total number of genera	No. of endemic genera	%	Total number of species	No. of endemic species	%
Lachninae	14	3	14	36	24	66
Chaitophorinae	4	0	0	20	14	70
Drepanosiphinae	32	9	28	44	36	80
Pterocommatinae	1	0	0	1	1	100
Aphidinae	99	20	15	431	172	33
Greenideinae	12	2	17	77	55	71
Anoeciinae	3	0	0	10	9	90
Hormaphidinae	21	4	20	39	18	45
Pemphiginae	20	4	20	52	31	60
Family adelgidae						
Pineni	1	0	0	3	0	0
Adelgini	1	0	0	3	2	66
Total	208	42	20	716	362	50

TABLE 2

Probable origin of genera of Aphidoidea recorded from the Indian region

Family Aphididae	Total	Endemic	Palaearctic	Nearctic	Oriental (Other than Indian)	Ethiopian	Malayan
Lachninae	14	3	9	2	0	0	0
Chaitophorinae	4	0	3	0	1	0	0
Drepanosiphinae	32	9	19	1	3	0	0
Pterocommatinae	1	0	1	0	0	0	0
Aphidinae	99	20	58 + 6*	3	8	1	2
Greenideinae	12	2	4	0	4	0	2
Anoeciinae	3	0	3	1	0	0	0
Hormaphidinae	21	4	10	0	0	0	7
Pemphiginae	20	4	16	0	0	0	0
Family Adelgidae							
Pineus	1	0	1	0	0	0	0
Adelges	1	0	1	0	0	0	0
	208	42	131	7	16	1	11

* Holoarctic.

Majority of the aphid species of the region are known to occur in the Northern (Northeast, Northcentral, Northwest) temperate region which offer very favourable ecological conditions in terms of biotic and abiotic factors. A very high ratio of species to genera (little over 1 : 3) could be noted as also extremely high percentage of endemism; this latter fact is interesting specially when even in the subfamily Lachninae or Drepanosiphinae endemic species are seen to form more than 66-75% of the total fauna. Floral abundance and other temperate ecological conditions in the hills may be regarded as important contributing factors in the origin of Indian fauna.

The change of life cycle from holocyclic to anholocyclic and heteroecious to monoecious pattern may be noted in the members of many of the well-known groups like Lachninae, Chaitophorinae, Drepanosiphinae, Greenideinae, (holocyclic elsewhere) or Anoeciinae, Aphidinae, Hormaphidinae and Pemphiginae, (heteroecious elsewhere). A high percentage of polyphagism with suppression of polymorphism has also been noted in many species of the family. A trend in acquisition of new hosts, possibly to substantiate the loss of primary host in the heteroecious cycle, could also be noted.

However, sufficient study on the biology of most of the species which is lacking at present, may ultimately lead to some different picture, specially in the groups like Pemphiginae or Hormaphidinae. Suppression of sexual forms and multiplication by continuous parthenogenetic mode of reproduction has been accepted as a fact in the aphid life-cycle in the region, but unless the role of sexual forms which have so far been recorded, are fully understood, nothing conclusive can be arrived at.

The tremendous extension of our knowledge of the aphid fauna of the region in 1960's, and 1970's through extensive surveys, has contributed much to our understanding of the fauna of India and presently a similar trend emphasizing the biological studies of the aphids of the region is becoming essential to clear a number of unsolved taxonomic problems and to have a precise idea about the mode of life cycle, role of sexual forms and other associated riddles.

ACKNOWLEDGMENT

The author is thankful to the Director, Zoological Survey of India for providing working facilities.

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APHIDS OF GARHWAL HIMALAYA

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ABSTRACT

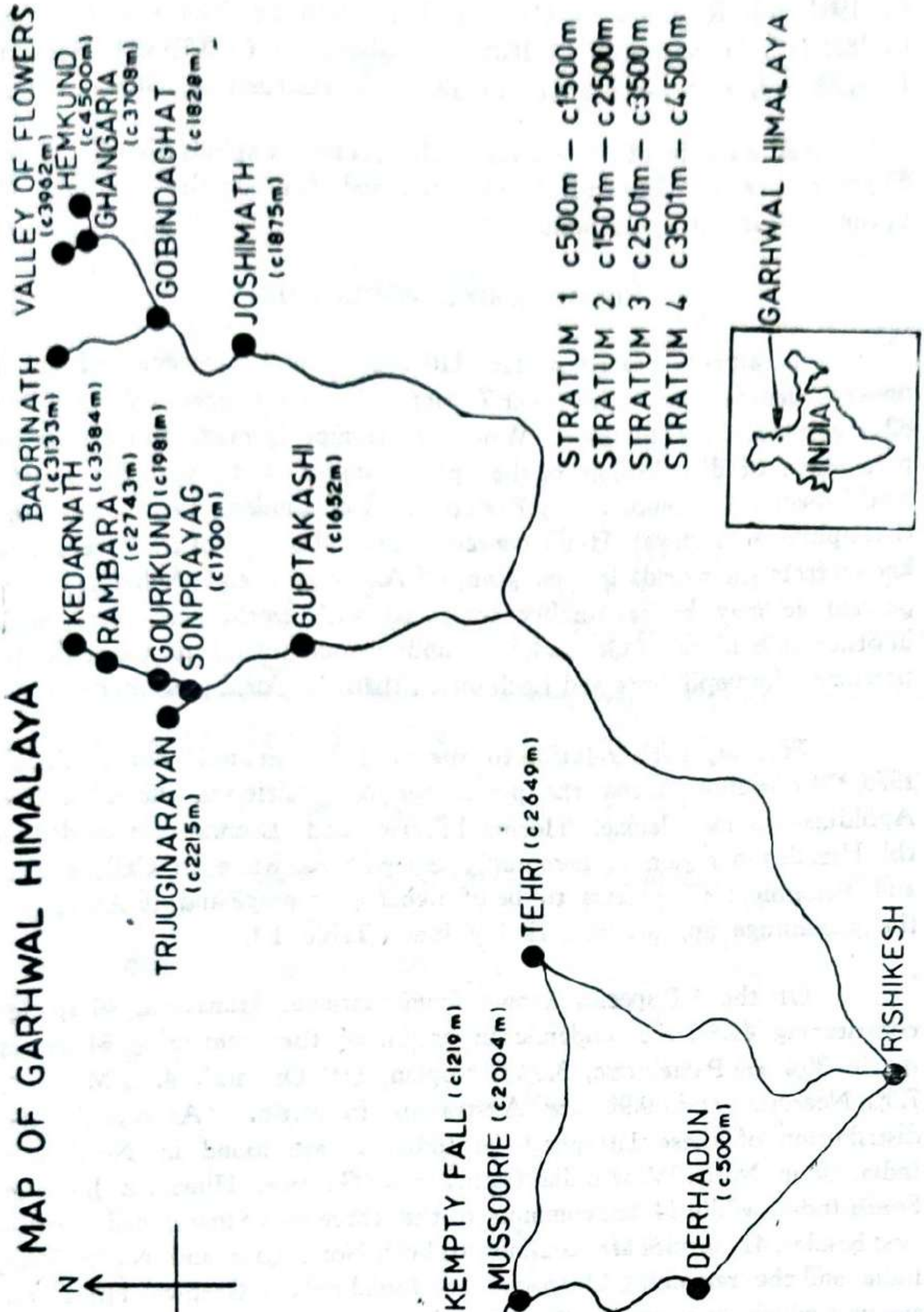
Onehundredten species of aphids belonging to 55 genera occur on 82 species of plants of 48 genera in Garhwal Himalaya. Seven species occur on roots of plants. Fortysix species are endemic.

INTRODUCTION

Systematic aphidological studies in North-West India particularly of Garhwal Himalaya have been made with a view to explore the aphid fauna of the area. Although some studies have been made on the aphids of the lower altitudes of the area, such as, Dehradun and Mussoorie by Buckton (1893, '96), David (1969), David *et al* (1968), Chakrabarti and Maity (1978), no comprehensive account of the aphid fauna and its probable origin, distribution and host-plant association is available.

Garhwal Himalaya of Uttar Pradesh is bounded on the north by Tibet, on the east by Kumaon, on the south by Gangetic plains and on the west by Himachal Pradesh. It lies between north latitude 29° 26′-15″ and 31°-5′-30″ and between east longitude 78°-18′-45″ and 80°-8′-0″ (Atkinson, 1973). The temperature ranges from—15°C to about 30°C (at the lower Terai elevations). The annual rainfall varies from 1564 mm to 2840 mm. This area, thus offers climatological variations with a rich floral assemblage. The area has been classified into tropical, sub-tropical, temperate and alpine zones, extending from the lower Terai vegetation to the snow line and beyond (Mani, 1973).

Six surveys have been undertaken in different regions of Garhwal Himalaya during summer (May to July) and winter (October to December) since 1975, in areas shown in the map between the altitude 500 m to 4,500 metres. The main survey localities so far covered are Dehradun (c 500 m), Mussoorie (c 2004 m), Tehri (c 2649 m), Guptakashi (c 1652


MAP OF GARHWAL HIMALAYA
N
KEMPTY FALL (c1219m)
MUSSOORIE (c2004m)
DERHADUN (c500m)
TEHRI (c2649m)
RISHIKESH
TRIJUGINARAYAN (c2215m)
GOURIKUND (c1981m)
SONPRAYAG (c1700m)
KEDARNATH (c3584m)
RAMBARA (c2743m)
GUPTAKASHI (c1652m)
BADRINATH (c3133m)
JOSHIMATH (c1875m)
GOBINDAGHAT (c1828m)
VALLEY OF FLOWERS (c3962m)
HEMKUND (c4500m)
GHANGARIA (c3708m)
STRATUM 1 c500m – c1500m
STRATUM 2 c1501m – c2500m
STRATUM 3 c2501m – c3500m
STRATUM 4 c3501m – c4500m
GARHWAL HIMALAYA
INDIA

m), Trijuginarayan (c 2215 m), Sonprayag (c 1700 m), Gourikund (c 1981 m), Rambara (c 2743 m), Kedarnath (c 3584 m), Joshimath (c 1875 m), Gobindaghat (c 1828 m), Ghangaria (c 3798 m), Hemkund (c 4,500 m), Valley of Flowers (c 3962 m), Badrinath (c 3133 m) etc.

As a result of the surveys, 110 species of aphids distributed over 55 genera are now known from the area and this constitutes about 17% of the total Indian aphid fauna.

ORIGIN AND DISTRIBUTION

As already stated, so far, 110 species and subspecies of aphids under 55 genera distributed over 7 subfamilies have been collected from 82 species of host plants. When an attempt is made to correlate the percentage of distribution of the species under study with the existing world species (as reported by Eastop and van Emden, 1972), it appears that aphids of Garhwal Himalaya constitute about 3% of the total species known from the world; in some groups (Anoeciinae and Aphidinae) the percentage may be favourably compared with world percentage, while in others it is higher (Greenideinae and Pemphiginae) or lower (Callipterinae, Hormaphidinae and Lachninae) than the world percentage.

Further, with relation to the total Indian aphid fauna (Ghosh, 1975, '78), it appears that the percentage composition in the subfamilies Aphidinae, Greenideinae, Hormaphidinae and Lachninae recorded in this Himalayan region is favourably comparable, while in Callipterinae and Pemphiginae it seems to be of higher percentage and in Anoeciinae the percentage appears remarkably low (Table 1).

Of the 110 species known from Garhwal Himalaya, 46 species constituting 41.8% are endemic in origin, of the remaining 64 exotic species 30% are Palaearctic, 3.6% Ethiopian, 11% Oriental, 4.5% Malayan, 7.3% Nearctic and 0.9% are Australian in origin. As regards the distribution of these 110 species in India, 18 are found in North-East India, 24 in North-West India (other than Garhwal Himalaya), one in South India, while 14 are common to the three above mentioned territories; besides, 41 species are common to both North-East and North-West India and the remaining 12 species are found only in Garhwal Himalaya, amongst which one species, ***Drepanosiphum oregonensis*** Granovsky, is new to India.

TABLE 1

Comparative studies of aphid species under different subfamilies

Sub-family	From all over world		From India		From Garhwal Himalaya	
	Number	% over total	Number	% over total	Number	% over total
Anoeciinae	36	0.9	9	1.3	1	0.9
Aphidinae	2277	61.7	404	62.3	66	60.0
*Callipterinae	536	13.5	60	9.3	13	11 8
Greenideinae	83	2.3	68	10.5	11	10.0
Hormaphidinae	160	4.3	37	5.7	4	3.6
Lachninae	336	9.1	33	5.0	5	4.5
Pemphiginae	267	7.2	37	5.7	10	9.0
Total	3695		648		110	

* Callipterinae is used after Higuchi (1972).

STRATIGRAPHIC DISTRIBUTION

Collection localities in Garhwal Himalaya can be considered under 4 strata viz.,

Stratum 1 localities between 500 — 1500 metres
Stratum 2 localities between 1501 — 2500 metres
Stratum 3 localities between 2051 — 3500 metres
Stratum 4 localities between 3501 — 4500 metres

Table 2 shows the percentage of genera and species occurring in each stratum. It becomes evident that the subfamily Aphidinae is predominant in all the strata, and strata 2 and 3 offer higher number of genera and species while the number appears to be lower in the stratum 4.

Subfamily Anoeciinae : Very poorly represented and found only in stratum 2 (Table 2). Only 1 species under one genus has been collected from the area under study.

TABLE 2

Number and percentage of aphid genera and species of different subfamilies occurring in different altitudinal strata of Garhwal Himalaya.

Sub-family	Total number from the area under study		Number of genera and species							
			Stratum 1 (500 - 1500 m)		Stratum 2 (1501 - 2500 m)		Stratum 3 (2501 - 3500 m)		Stratum 4 (3501 - 4500 m)	
	Genera	species	Genera(%)	Species(%)	Genera(%)	Species(%)	Genera(%)	Species(%)	Genera(%)	Species(%)
Anoeciinae	1	1	—	—	1 (2.1)	1 (1.0)	—	—	—	—
Aphidinae	28	66	17 (70.0)	31 (75.6)	26 (56.9)	59 (63.4)	19 (63.3)	31 (70.4)	13 (68.4)	20 (70.4)
*Callipterinae	9	13	1 (4.1)	1 (2.4)	4 (8.7)	6 (6.4)	4 (13.3)	5 (11.3)	4 (21.0)	6 (21.4)
Greenideinae	4	11	—	—	4 (8.7)	11 (11.8)	3 (10.0)	4 (9.0)	1 (5.2)	1 (3.5)
Hormaphidinae	4	4	3 (12.5)	3 (7.3)	2 (4.3)	2 (2.1)	1 (3.3)	1 (2.2)	—	—
Lachninae	3	5	—	—	3 (6.5)	4 (4.3)	1 (3.3)	1 (2.2)	—	—
Pemphiginae	6	10	3 (12.5)	6 (14.6)	6 (13.0)	10 (10·7)	2 (6.6)	2 (4.5)	1 (5.2)	1 (3.5)
Total	55	110	24 (43.6)	41 (37.2)	46 (83.6)	93 (84.5)	30 (54.5)	44 (40.0]	19 (34.5)(	28 (25.4)

* Callipterinae is used after Higuchi (1972).

Subfamily Aphidinae: Appears to be the largest group in all the strata and amongst the other subfamilies as well; the highest percentage of genera and species is found in stratum 1 and the lowest in stratum 2.

Subfamily Callipterinae: Found in all strata and the maximum percentage occurs in stratum 4. It appears that the percentage gradually increases with the increase of altitude, and the climatic areas located between the altitude 3500 to 4500 metres provide the most favourable conditions for the distribution of Callipterinae.

Subfamily Greenideinae: Highest percentage of genera is noted in stratum 3, while highest percentage of species is recorded in stratum 2. No species of this group has been recorded from stratum 1, perhaps due to the lack of host plant families at lower altitude.

Subfamily Hormaphidinae: Very poorly represented; only four species of 4 different genera are known, of which the maximum number of genera and species are found in stratum 1, and with increasing altitude the number decreases gradually; no species is recorded from stratum 4.

Subfamily Lachninae: Found only in strata 2 and 3 in low percentage indicating that the group prefers cooler region between c 2000 m and c 3500 m, where the favourable host plant, mainly *Quercus* spp., are abundant.

Subfamily Pemphiginae: Occurs in all strata appearing in abundant number in stratum 2 (however, highest percentage of distribution is found in stratum 1) and with increasing altitude the number of species and genera gradually decreases.

HOST-PLANT ASSOCIATION

Host-plants of aphid fauna in the region belong to 82 species under 48 genera distributed over 31 plant families. Most of the aphids appear to be host-specific but a few species shows a wide host-plant range. Table 3 indicates that plants of 11 families harbour the maximum number of aphid species and of these host-plant families, those of Compositae and Graminae appear to be the more favoured hosts than the others.

TABLE 3

Family of host-plant	*Number of aphid species*
Betulacae	6
Compositae	22
Fagaceae	12
Graminae	20
Juglandaceae	2
Rosaceae	12
Rubiaceae	4
Sapindaceae	7
Salicaceae	7
Solanaceae	8
Polygonaceae	8
Total	108

Aphids of the subfamily Aphidinae is the most predominant group on major economic crops in the area (cereal crops, pulses, spices, narcotic, ornamental plants and vegeatables), while the fibre crops are infested by the members of Hormaphidinae and the forest trees mainly by the members of other subfamilies.

ACKNOWLEDGMENTS

The authors are thankful to Dr. A. K. Ghosh, Zoological Survey of India, Calcutta for his kind collaboration, to the authorities of the University of Kalyani for providing financial assistance, to the Head, Department of Zoology, University of Kalyani for laboratory facilities and to Mr. K. M. Vaid, Forest Research Instuitute, Dehradun, Uttar Pradesh for kindly identifying the host plants.

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VERTICAL DISTRIBUTION OF APHIDS OF MANIPUR

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INTRODUCTION

Manipur lies on the northeast corner of India between 23.83° and 25.68°N latitude and 93.05° and 94.78°E longitude and is comprised of 5 districts, north, south, east, west and central. The total area of the state is about 22,356 sq. kilometres of which about 20,000 sq. kilometres form the hilly tracts. In the hilly region the altitude varies from nearly 300 metres to 3,050 metres. The state is marked by a natural lake covering an area of about 60 sq. kilomitres.

The climate of Manipur is salubrious. The different elevations in the state admit variation in temperature and relative humidity. However, temperature and relative humidity of the state usually vary from 0.5°C to 32.5°C and 67% to 74% respectively. The mean annual rainfall for the valley has been estimated at about 1413 mm.

The aphidological survey undertaken in the state have resulted in the collection of 156 species from 55 localities situated in altitudes ranging between 300 and 2400 metres. These aphids have been found to be distributed over seven subfamilies, viz., Anoeciinae, Aphidinae, Callipterinae*, Greendeinae, Hormaphidinae, Lachininae and Pemphiginae.

The overall picture of stratigraphic distibution of aphids in the area of survey shows that the stratum 300—600 metres is poor in aphid representation while maximum concentration of aphids could be observed in the stratum 601—1200 metres (Table 2) and this is mostly because of the concentration of the members of the subfamily Aphidinae as well as the number of host plant species exploited by them. It is also observed that

* After Higuchi (1972).

the numbers of Anoeciinae, Callipterinae, Lachninae and Pemphiginae could not be found in the lowest stratum i. e., 300—600 metres. Moreover, the first named subfamily could not be recorded from the highest stratum, 1801—2400 metres. Callipterine and lachnine aphids exhibit preference for higher altitudinal strata since the number is highest in the stratum 1801—2400 metres even though fewer examples could be found in strata ranging between 601—1800 metres. Consideration of the number of host plant species infested by these insects reveals that they are slightly more frequent in the highest stratum i.e., 1801—2400 metres. Likewise concentration of greenidine and hormaphidine aphids is maximum in the stratum extending from 1201 to 1800 metres. Pemphigine aphids are equally distributed in the different strata above 300—600 metres irrespective of the number of host plantspecies exploited by them in different strata.

MATERIALS AND METHODS

The area under the present study having localities of varying altitudes has been divided into 4 altitudinal strata, viz., stratum 1: 300—600 metres, stratum 2 : 600—1200 metres, stratum 3 : 1201—1800 metres and stratum 4 : 1801—2400 metres. Aphid specimens were collected from different localities (vide map) of each of these strata at regular intervals (bimonthly) through regular trips.

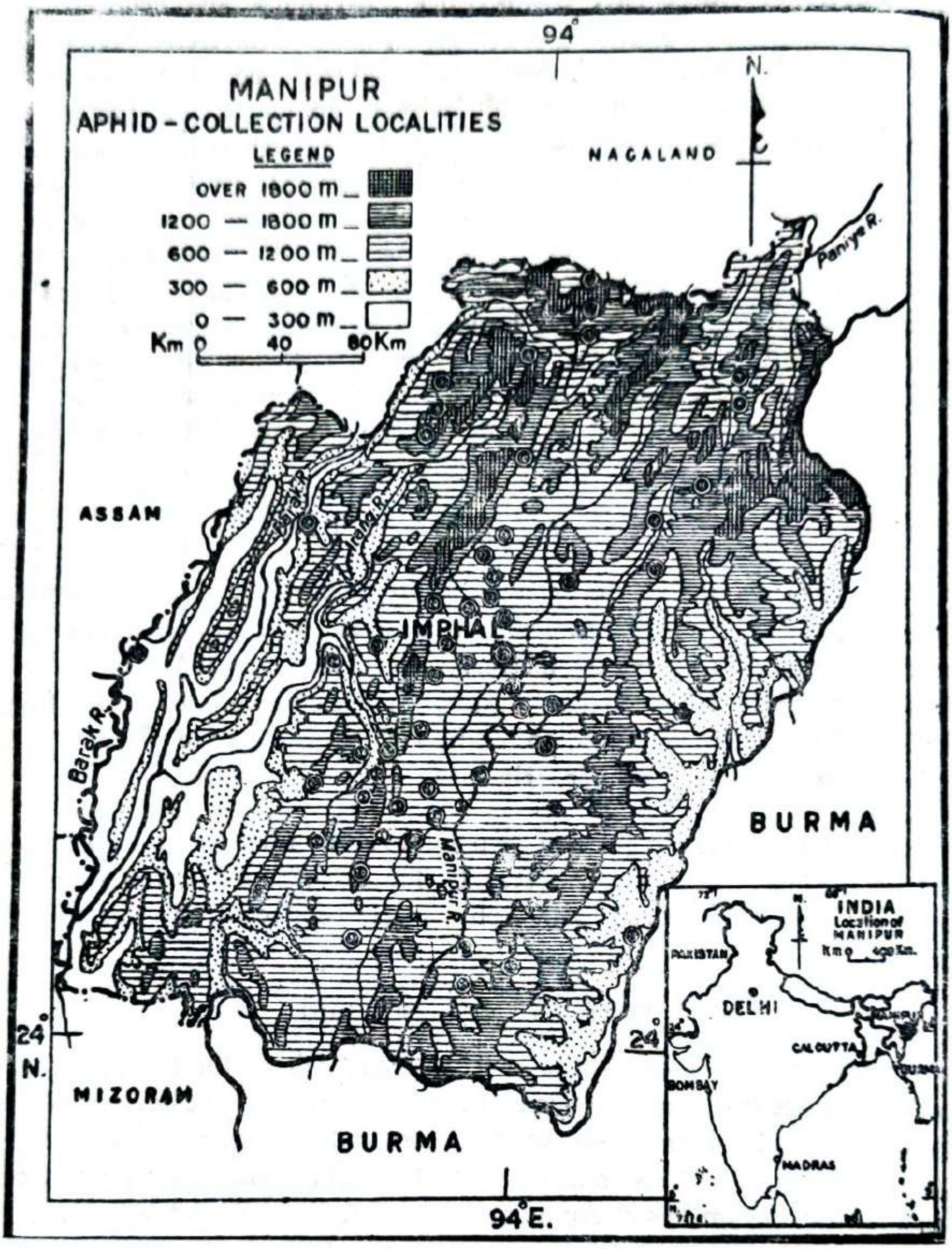
During each collection trip detailed information on (1) species and family of host plants infested, (2) nature of aphid infestation and (3) organisms associated with aphids were collected as carefully as possible.

RESULTS AND DISCUSSION

From the area of the present study which forms a part of the northen fringe of Oriental region and is close to Palaearctic region, 156 species of aphids distributed over 86 genera under 7 subfamilies (Table 1) could be recorded. This indicates that the aphid fauna here is represented from all the subfamilfes of Aphididae.

Vertical distribution of these aphids (Table 1) is discussed below at subfamily level.

Anoecinae : The subfamily is represented by only 2 species in this region (Table 1). It is interesting to note that these 2 species have a rather restricted distribution in localities situated between 601 and 1800 metres.



Aphidinae: Members of this subfamily form the major bulk of aphid fauna of the region. They have been found to occur all throughout the area of the present study. Though ubiquitous in the area yet, this sub-family also exhibits some preference with regard to its prevalence in different altitudes. Maximum number of species under this subfamily could be recorded in localities lying between altitudes 601 and 1200 m., while minimum number of species could be found in stratum 1, i. e., 300-600 m. The number of species available in the stratum 3, i. e., 1201-1800 m and stratum 4, i. e., 1801-2400m though less than that obtained in the stratum 2, i. e., 600 and 1200 m. is much higher than that in stratum 1, i. e., 300-600 m.

It appears that the localities situated between 600 and 1200 metres afford the most congenial condition for the preponderance of this group in respect of number of species.

Callipterinae : The species belonging to this subfamily could be recorded in localities above 600 metres and they were found to be slightly more prevalent at stratum 4, i. e., 1800 and 2400 metres. The somewhat restrictive occurrence of the members of this subfamily in comparatively high altitude areas and its complete absence in localities belew 600 metres leads one to think that comparatively cooler climate available in high altitude areas is preferred by the members of this subfamily.

Greenideinae : Like the members of the subfamily Aphidinae the species belonging to this subfamily though could be recorded from all the altitudinal strata, were more predominant in localities situated between 1200 and 1800 m i. e., stratum 3. The minimum number of species were found in the lowest stratum i. e , 300 and 600 m as was also the case with the members of the subfamily Aphidinae. From the pattern of distribution of the greenideine aphids occurring in different altitudinal strata the preferential climatological conditions of these aphids appear to be intermediate between those of Aphidinae and Callipterinae.

Hormaphidinae : The pattern of distribution of the members of this group in different altitudinal strata follows more or less the same trend as observed in case of Greenideinae.

Lachninae : This suhfamily is poorly represented. The pattern of distribution of the species in different altitudinal strata also follows a trend similar to that of Anoeciinae. The species under this subfamily could be obtained only from localities situated between 600 and 2400 metres.

Pemphiginae : Pemphiginae is represented by 9 species in the area of the present study. These were collected from localities lying between

600 and 2400 m. The occurrence of this subfamily in different altitudinal strata conforms with the distribution pattern of Callipterinae i. e., they, are non-existent in low altitude areas (300-600 m).

TABLE 1

Number of aphid species at different altitudinal strata in Manipur state

Subfamily	Total no. in the area	No. of species at different strata			
		300-600m	601-1200m	1201-1800m	1801-2400m
Anoeciinae	2 (2)*	—	2	1	—
Aphidinae	90 (45)	9	69	46	30
Callipterinae	11 (8)	—	5	5	6
Greenideinae	25 (10)	5	11	18	7
Hormaphidinae	14 (11)	3	9	10	3
Lachninae	5 (4)	—	3	2	5
Pemphiginae	9 (6)	—	4	4	4
Total	156 (86)	17	103	86	55

* Figures within parenthesis indicate number of genera.

It has earlier been stated that the maximum number of species under Aphidinae, Greenideinae and Hormaphidinae, and Lachninae and Callipterinae were found in altitudinal strata 601-1200, 1201-1800 and 1801-2400 metres respectively. A positive correlation between the number of aphid species available in a stratum and the number of plant species exploited by them has not always been obtained (Table 2). However, in some cases (viz., Aphidinae, Lachninae) such correlation is not difficult to be achieved. It has been pointed out before that the representation of the number of Anoeciinae and Pemphiginae is scanty. So no attempt is made to draw a relationship between the distribution of aphid species of these two subfamilies and the host-plant species infested by them. From tables 1 and 2 it appears that stratum 2 extending from 601 to 1200 m is most congenial for the members of Aphidinae from

TABLE 2

Distribution of aphids and host plants in different altitueds of Manipur, India

subfamily	Number at diferent strata											
	300 - 600 m			601 - 1200 m			1201 - 1800 m			1801 - 2400 m		
	No. of aphid species	No. of host plant species	No. of plant family	No. of aphid species	No. of host plant species	No. of plant family	No. of aphid species	No. of host plant species	No. of plant family	No. of aphid species	No. of host plant species	No. of plant family
Anoeciinae	—	—	—	2	2	1	1	3	2	—	—	—
Aphidinae	9	12	11	69	167	62	46	73	33	31	36	19
Callipterinae	—	—	—	5	7	5	5	5	5	6	6	5
Greenideinae	5	4	3	11	18	11	19	15	11	7	7	6
Hormaphidinae	3	2	1	9	10	4	11	10	4	3	4	1
Lachninae	—	—	—	3	3	2	2	3	3	5	5	5
Pemphiginae	—	—	—	4	9	4	4	4	2	4	4	2

the view point of availability of host plants. Incidentally, for Greenideinae the stratum for species abundance extends from 1201 to 1800 m where the number of host plant species for this group of aphids is also substantially high though not highest. The same also holds good for Hormaphidinae.

Vertical distribution of the aphids in Manipur as discussed is in agreement with the findings of Ghosh and Raychaudhuri (1977) in respect of aphids occurring in Darjeeling district of West Bengal and Sikkim.

Preponderance of both aphid species and their host plants in a particular altitudinal stratum strongly support that favourable biotic conditions are essential for aphid abundance.

ACKNOWLEDGMENTS

The authors are thankful to the University Grant Commission, New Delhi for partly financing the project, to Botanical Survey of India for identification of the plant materials and to the Head of the Dept. of Zoology, Calcutta University for providing laboratory facilities.

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The Aphids : 99-102

A STUDY ON THE SEXUALES OF APHIDS OF HIMACHAL PRADESH, N. W. INDIA

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ABSTRACT

Subfamilywise breakup of aphid sexuales of Himachal Pradesh is given. Males of 5 species/subspecies, *viz.*, *Cinara abieticola tenuipes* Chakrabarti and Ghosh, *Impatientinum impatiense dalhousiensis* Verma, *Masonaphis* (*Neomasonaphis*) *inulae* Ghosh and Raychaudhuri, *Takecallis affinis* sp. nov. and *Tinocalloides montanus* Basu; and oviparae of 5 species/subspecies *viz.*, *Amphicercidus indicus* David *et al.*, *Cavariella nigra* Basu., *Eutrichosiphum* (*Paratrichosiphum*) *alnicola* Basu, *Indocinara hottesis* Ghosh *et al.* and *Takecallis affinis* sp. nov. are hitherto reported for the first time.

INTRODUCTION

Under the diverse climatic conditions prevailing in India, the aphids reproduce generally by parthenogenetic viviparae and sexual forms have been recorded in a very few cases. About 716 species of aphids belonging to about 208 genera (Ghosh, A. K., 1983) of which about 362 species in 42 genera are endemic, are known from India, and about 10% of these species are known to produce sexuales.

Himachal Pradesh is a part of the N. W. Himalayas having a deeply broken topography, complex geological structures and a rich temperate and subtropical flora of different localities; most of the rainfall is received in monsoon (July-August); the average annual rainfall is about 1523 mm. and temperature ranges from 2°C (minimum) to 35°C (maximum).

About 220 species (of which 84.5% are known by parthenogenetic viviparae only) occur in Himachal Pradesh; sexuales could be obtained for 14.5% of the species and these present about 50% of the sexuales recorded from India. Sexuales were collected during winter (November — January) when the average temperature varies between 5°C and 13°C and mean day length covers 8 hours. It is observed that maximum number of aphid species occurs at the elevations ranging from *Ca* 1,000 m to 3,000 m with a sharp decline in the species number above the altitude *Ca* 3,800 m. Field data also depict that nearly 80% of aphids concentrate at the altitudinal level of *Ca* 2,000 m which correlates with the occurrence of sexuales in the area.

Out of 34 species/subspecies for which sexuales are so far known from the region, only males of 13 species/subspecies, only oviparous females of 8 species/subspecies and both males and oviparae of 9 species/subspecies have been recorded; these are shown in Table 1.

TABLE 1

Subfamilywise break-up of the aphid sexuales of H. P.

Subfamily Aphidinae	Only ♂	Only ♀	Both ♂ & ♀	Total
Tribe Aphidini	3 (2)	1	2 (1)	6
Tribe Macrosiphini	8 (7)	8 (8)	5 (4)	21
Subfamily Lachninae	1	1	—	2
Callipterinae	1	1	2 (2)	4
Greenideinae	—	1	—	1
Hormaphidinae	—	—	—	—
Pemphiginae	—	—	—	—
Total species	13 (11)	12 (12)	9 (7)	31

(The figure under parenthesis represents number of genera)

Of the obove sexuales, males of 5 species/subspecies viz., *Cinara abieticola tenuipes* Chakrabarti and Ghosh, *Impatientinum impatiense dalhousiensis* Verma, *Masonaphis (Neamasonaphis) inulae* Ghosh and Raychandhuri, *Takecallis affinis* sp. nov. and *Tinocalloides montanus*

Basu; and oviparae of 5 species/subspecies viz., ***Amphicercidus indicus*** David *et al.*, ***Cavariella nigra*** Basu, ***Eutrichosiphum (Paratrichosiphum) alnicola*** Basu, ***Indocinara hottesis*** Ghosh *et al.*, and ***Takecallis affinis*** sp. nov. were hitherto unknown. Detailed descriptions of these sexual morphs will be published elsewhere.

DISCUSSION

An analysis of the collection data indicates that (either male/ ovipara) at least seven definite species/subspecies viz., ***Aphis clematidis simlaensis*** Kumar and Burkhardt, ***A. pollinosa*** Walker, ***Acyrthosiphon rubi*** (Narz.), ***Amphorophora ampullata bengalensis*** H. R. L., ***Cavariella nigra*** Basu, ***Lipaphis erysimi*** (Kalt.), and ***Uroleucon longisetosus*** Chakrabarti and Verma whose sexuales were collected along with the parthenogenetic morphs from the same host, in the same season, may be leading a holocyclic mode of life cycle on the primary host at the higher elevations. It may be noted that some of these species occur only in parthenogenetic morphs elsewhere in India in different seasons of the year on the same host-group.

It is also interesting to note that the sexuales of the above mentioned spp./subspp. were collected during October when the day length is rather longer (approx. 10 hours) and temperature is evidently higher than that during December-January. In view of the above observations, it appears to be not in conformity with the conventional idea that only short day lenth and low temperature help in the production of sexuales in aphids. However, in most of the cases of the present study, the discovery of sexuales at the elevations during colder part of the year (when the day length is rather short and temperature low) tallies with the observations of other workers, although these have not been considered as the only determining factors for production of sexuales by some authors (Bodenheimer and Swirski, 1957). Whether the host plants have got any bearing upon the production of sexuales can only be judged on more detailed data based on the collections of aphids on primary and secondary hosts, if any, at different seasons of the year. Further, whether the oviparae of aphids in this region lay viable eggs or not, is yet to be investigated. Exploration of the aphid fauna through extensive and intensive surveys in the area together with biological studies would perhaps help to find the clues as to the causative factors for the production of the sexuales in aphids in the region under study.

ACKNOWLEDGMEMTS

One of the authors (L. K. Ghosh) is thankful to Dr. T. N. Ananthakrishnan, Director, Zoological Survey of India, Calcutta, for providing necessary working facilities and to Dr. A. K. Ghosh, Superintending Zoologist, Zoological Survey of India, for valuable suggestions.

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The Aphids : 103.110

III. MORPHOLOGY, ANATOMY AND DEVELOPMENTAL BIOLOGY

ON THE ALIMENTARY CANAL OF THE MAIZE APHID, *RHOPALOSIPHUM MAIDIS* (FITCH)

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ABSTRACT

The morphology aud histology of the alimentary canal of the maize aphid, *Rhopalosiphum maidis* (Fitch) have been studied. The alimentary canal is a long coiled tubular structure consisting of three primary regions viz., foregut, midgut and hindgut. The filter chamber and the Malpighian tubules are absent. Salivery glands are absent. The alimentary canal is surrounded by a layer of circular muscles and possesses a single layer of epithelial cells. An oesophageal valve is present at the junction of the oesophagus and the stomach.

INTRODUCTION

Though fragmentary reports on the aphid gut are on record (Knowlton, 1925; Miller, 1932; Pelton, 1938; Smith, 1939), the credit of a detailed study goes to Forbes (1964), who studied the anatomy and histology of the gut of ***Myzus (Nectarosiphon) persicae*** (Sulzer). Of late, Saxena and Chada (1972) described the digestive system of the green bug, ***Schizaphis graminum*** (Rondani). However, studies on the alimentary canal of other species of aphids are still lacking. The present work was therefore undertaken to describe the morphology and histology of the alimentary canal of the maize aphid, *Rhopalosiphum maidis* (Fitch).

MATERIALS AND METHODS

Fresh live adult apterous virginoparae of *R. maidis* collected on maize were anchored in melting paraffin and dissected in physiological saline under a dissecting microscope. For histological study the alimentary canal was fixed in alcoholic Bouin's fluid, sections were cut at 5 to 7 μ and stained in haematoxyline and eosine.

MORPHOLOGY

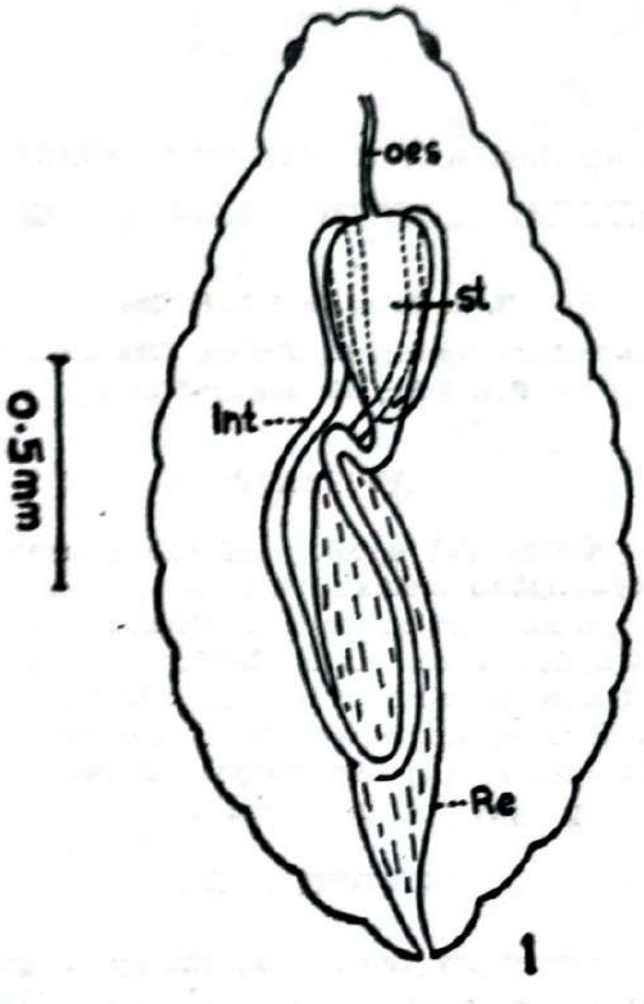


Fig. 1—*Rhopalosiphum maidis* (Fitch): alimentary canal, oes-oesophagus; st—stomach: Int—intestine: Re—rectum.

The alimentary canal of *R. maidis* (Fig. 1) is a long tube running from mouth to anus in a convoluted course and is coiled in the middle. It consists of three primary divisions: the foregut or oesophagus, mid gut and hind gut or rectum. The oesophagus is the shortest of all parts. It has been termed as fore intestine by Knowlton (1925), stomodaeum by Snodgrass (1935) and foregut by Roeder (1953). The oesophagus is very thin and extends from the head to the mesothorax, where it opens into a dilated bulb-like stomach. The mid gut can be differentiated into a bulbous stomach and a narrow intestine. Various names have also been assigned to the stomach, such as, mesenteron, midgut, mid-intestine and ventriculus (Forbes, 1964; Saxena and Chada, 1972). In *R. maidis* the stomach is broadest at its anterior end and gradually narrows towards the posterior. It lies close beneath the dorsal wall. At the posterior end in between the first and second abdominal segments it opens into the intestine. The intestine leaves the stomach ventrally, runs posteriorly, makes a 'U' turn in the region of the fifth and the sixth abdominal segments, continues anteriorly to the mesothoracic region, then turns and finally dilates into a transparent membranous rectum. The U-like loop of the intestine is quite separate from the stomach as there is no 'filter chamber' in this species of aphid. The hind gut broadens suddenly and proceeds caudad narrowing again towards the anus, which is situated just below the cauda.

HISTOLOGY

Oesophagus :

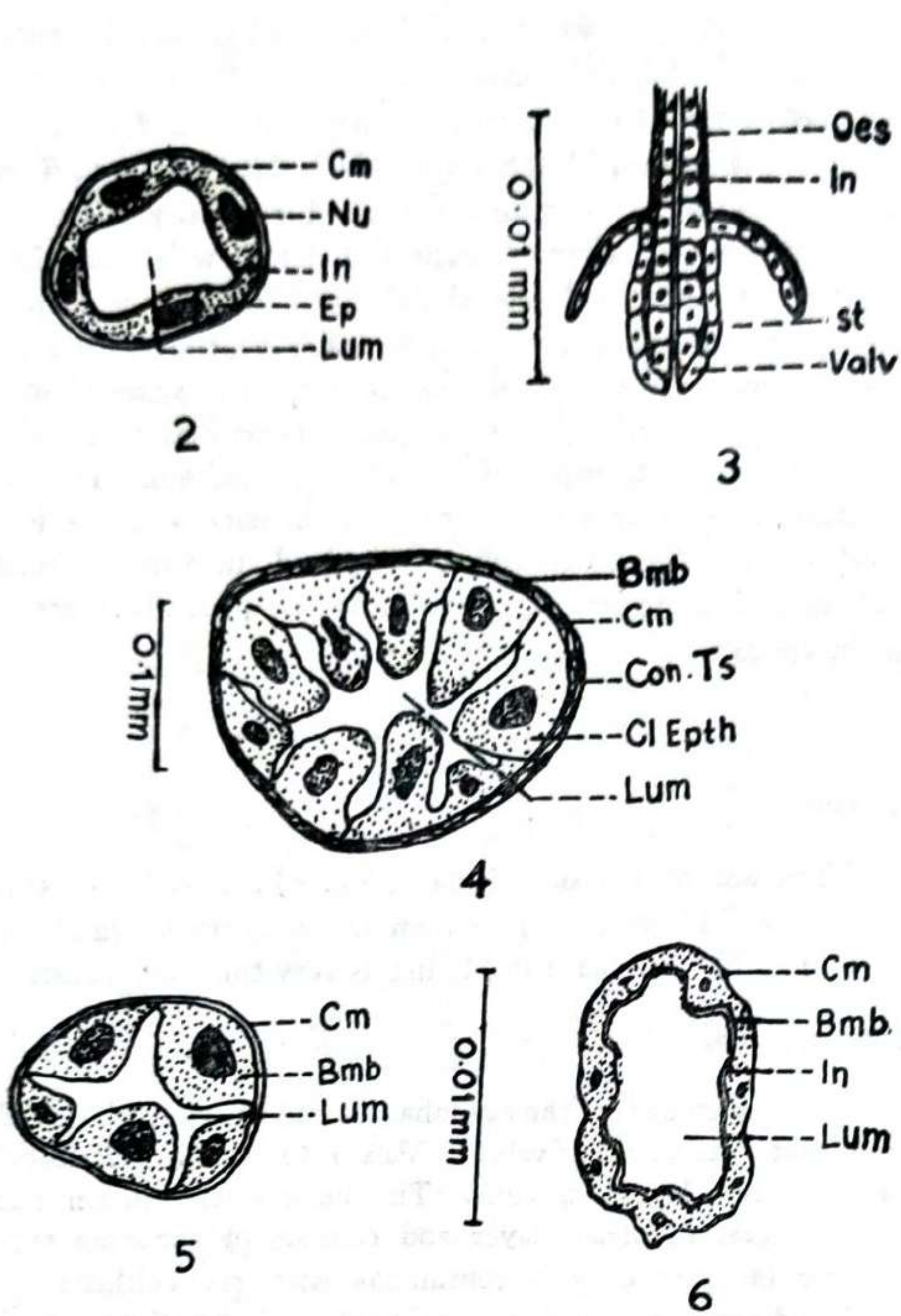
The wall of the oesophagus (Fig. 2) consists of a thin layer of circular muscle fibres (Cm) and an inner epithelial layer of flattened cells (Ep). The intimal (In) lining is very thin and smooth.

Oesophageal valve

The openiug of the oesophagus into the stomach is indicated by a prominent oesophageal valve (Valv) (Fig. 3). Histologically the valve shows two layers of cells. The inner layer is in continuation with the oesophageal epithelial layer and consists of the same type of cells. The outer layer of cells is continuous with the epithelial layer of the stomach and consists of cells similar to that of the epithelial layer of the stomach (St). The intimal lining terminates at the end of the oesophageal valve (Valv) and is not continued to the outer epithelial layer which forms the inner lining of the stomach.

Stomach :

The epithelial layer of the stomach (Fig. 4) consists of a layer of large columner epithelial cells (Cl Epth). Small basal cells are also found in some sections just beneath the columnar cells. The anterior portion of the stomach contains more number of columnar cells than that of the



Figs. 2-6—*Rhopalosiphum maidis* (Fitch) :

2 — T. S. of oesophagus.
3 — L. S. through the oesophagus and the stomach showing the oesophageal valve.
4 — T. S. through the stomach.
5 — T. S. through the intestine.
6 — T. S. through the rectum.

(Bmb—basement membrane; Cl Epth—columnar epithelial cells; Cm—circular muscle fibre; Con Ts—connective tissue; Ep—Epithelium; In—intima; Lum—lumen, Nu—nucleus; Oes—oesophagus; St—stomach; Valv—Oesophageal valve.)

posterior portion. The nuclei of the cells are fairly large and oval. The columnar cells are of different shapes and sizes viz., lobate, cylindrical and pyramidal. The apical cytoplasm of the cells are more granular than in the central and basal region of the cells. No intimal lining or peritrophic membrane is describable in the stomach.

The epithelial layers are bounded externally by a connective tissue layer (Con. Ts), which is closely associated with the basement membrane (Bmb) of the epithelial cells. Only one layer of circular muscle covers the stomach.

The lumen (Lum) of the stomach is stellate type.

Intestine :

Histologically there is no sharp line of demarkation between the stomach and the intestine (Fig. 5). As the stomach narrows posteriorly to give rise to the intestine, the lumen of the later is considerably reduced throughout the entire length until it reaches the rectum.

The intestine consists of five large triangular epithelial cells in transverse section, their apices projecting into the lumen and almost occluding it. The basement membrane and the muscular layer are like those of the stomach.

Rectum :

The wall of the rectum (**Fig.** 6) is very thin, consists of a single layer of cells with indistinct intercellular membrane and small nuclei. The nuclei typically occur in small areas of cytoplasum which project slightly into the lumen. A thin intima (In) lines the lumen (Lum).

The lumen is comparatively large in this part of the alimentary tract.

Only one layer of circular muscle covers the rectum.

DISCUSSION

In most Homoptera an ususual modification of the alimentary canal produces an organ known as the 'Filter chamber' (Snodgrass, 1935). In the membracids the end of the mid gut forms a loop, penetrates the outer wall and applies itself to the epithelial layer of the anterior portion of the midgut as found in ***Trlcentrus albomaculatus*** (Kershaw, 1913) and ***Oxyrachis tarandus*** (Chandel, 1958, 1960). In the cercopid, the midgut forms a dilated pouch, and the lower end of the midgut and a part of the malpighian tubules lie coiled between its epithelium and connective tissue coat, and the lower part of the midgut makes a zigzag course within the filter chamber, as found in *Ptyelus nebulosus* (Behura and Ray, 1971). In the jassids the filter chamber is present in some while, absent in the others (Saxena, 1955). Wigglesworth (1965) states that among the honeydew producing aphids in some species, a filter chamber is present and absent in others.

The filter chamber and malpighian tubules are absent in *R. maidis*. Forbes (1964), and Saxena and Chada (1972) also report the absence of the filter chamber and malpighian tubules in *M. persicae* and *S. graminum* respectively.

Jassids possess a pair of principal and a pair of accessory salivary glands (Saxena, 1955). Behura and Ray (1971) do not report the presence of any such gland in *P. nebulosus*. Among aphids, two pairs of simple sac-like glands are located in the prothorax of *Eriosoma* and *Lachnus*; in *Viteus vitifolli* and *Adelges lapponicus*, three pairs have been described (Wiggleesworth, 1965).

No salivary gland could be made out in *R. maidis*. Forbes (1964), and Saxena and Chada (1972) also did not find any in *M. persicae* and *S. graminum*.

Forbes (1964), and Saxena and Chada (1972) have described the presence of longitudinal folds in the epithelial layer of the oesophagus in *M. persicae* and *S. graminum*. In *R. maidis* similar structures could not be made out.

Martini (1958) reports that in *Aphis fabae* the intimal lining of the inner epithelial layer of the oesophageal valve surrounds the end of the valve in the form of a sac-like structure, while in *R maidis* it stops at the end of the oesophageal valve, and is not continued to the outer epithelial layer. Saxena and Chada (1972) have reported similar arrangement in *S. graminum*.

The stomach of *R .maidis* consists of a single layer of columnar epithelial cells, and no intimal lining or peritrophic membrane is distinguishable. Similar is the case in ***M. persicae*** (Forbes, 1964) and ***S. graminum*** (Saxena and Chada, 1972). However, Knowlton (1925) reports the presence of a peritrophic membrane in ***Longistigma carvae*** (Harris). The epithelial layer of the stomach is bounded externally by a connective tissue layer, which is closely associated with the basement membrane of the epithelial cells. Forbes (1964) termed it as 'tunica propria'. Knowlton (1926) reports the presence of two muscular layers, one longitudinal and the other circular, surrounding the stomach in *Lachnus carvae*. Forbes (1964), and Saxena and Chada (1972) describe only one circular muscle layer covering the stomach in ***M. persicae*** and ***S. graminum***. Same is the case in ***R. maidis***.

In *R. maidis* the T. S. of intestine consists of five large triangular epithelial cells. Similar findings have been reported in ***M. persicae*** (Forbes, 1964) and in ***S. graminum*** (Saxena and Chada, 1972).

The rectum is surrounded by a single layer of circular muscle in *R. maidis*., whereas Forbes (1964) reports the presence of a layer of circular muscles and a layer of longitudinal muscles in the rectum of *M. persicae*.

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The Aphids : *111-116*

STUDIES ON DEVELOPMENT AND REPRODUCTION OF FUNDATRICES OF COWPEA APHID, *APHIS CRACCIVORA* KOCH*

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ABSTRACT

The fundatrices required almost equal period to reach maturity as was observed in parthenogenetic viviparous nymphs. The average adult longevity of the fundatrix was 10.9 days whereas, parthenogenetic viviparous female could survive for 27.3 days.

The body shape of the fundatrix is different from that of the parthenogenetic viviparous female. The body length and width of the fundatrix are smaller than that of the parthenogenetic viviparous females. There is not much difference in various body part measurements of the fundatrices and the parthenogenetic viviparous females. On an average each fundatrix could reproduce 14.55 nymphs, of which 50.38% developed as alates and 49.62% developed as apterous parthenogenetic viviparous females.

INTRODUCTION

The various forms of *Aphis craccivora* Koch were successfully developed under controlled conditions of temperature and photoperiod in the laboratory on crown vetch, *Coronilla varia* L., by Radke ***et al*****.** (1972). In this paper results of critical study of the development of the fundatrices hatched out from the overwintered eggs of *A. craccivora* at 18.3°C constant temperature with 12 hr light : 12 hr dark period per day are presented. The measurements of taxonomically important body parts of the fundatrices are also reported.

MATERIALS AND METHODS

The overwintered eggs were collected on March 16 and April 1, 1971 from the experimental field of Crown vetch, *Coronilla varia* L., a

1. The work was carried out at the Pennsylvania State University, University Park, Pa. 16802 U. S. A.

leguminous plant, of the State College Centre County, Pennsylvania, U.S.A. These eggs were allowed to hatch at 18.3°C constant temperature with 12 hr of photoperiod/day in Percival growth Chamber. The fundatrices hatching out of the eggs were kept seperately in microcages on the twig of Crown vetch, *C. varia*. The microcages prepared were similar to those used by Radke *et al.* (1973). In all, 12 fundatrices were initially caged seperately of which only 9 could develop through all the stages and reproduce.

Four adult fundatrices were collected from the laboratory culture and preserved in 70% alcohol. They were then cleared in xylol and mounted in canada balsam for measurement of taxonomically important body parts

RESULTS AND DISCUSSION

The results obtained on the development of fundatrices indicated that the first, second, third and fourth stadium took 3.8, 2.9, 2.1 and 3 days respectively (Table 1).

TABLE 1

Mean duration in days spent in various developmental stages by fundatrices of the cowpea aphid, *Aphis craccivora* Koch at 18.3°C constant temperature with 12 hr photoperiod/day.

Sr. No. 1	Stages 2	Mean day *	± 3	SD.
1.	Ist instar	3.8	±	1.1
2.	IInd instar	2.9	±	0.8
3.	IIIrd instar	2.1	±	0.6
4.	IVth instar	3.0	±	0.9
5.	Days required to become an adult	12.4	±	1.2
6.	Prereproductive period	1.4	±	1.0
7.	Reproductive period	8.2	±	7.9
8.	Postreproductive period	1.2	±	1.3
9.	Longevity	10.9	±	8.3

*Mean is calculated from the observation of 9 samples.

Radke *et al.* (1973) observed 4.4, 2.6, 2.4 and 2.7 days for first, second, third and fourth stadium respectively in respect of development of the nymphs produced by the parthenogenetic viviparous female at 18.3°C. It is clear that fundatrices and the parthenogenetic viviparous nymphs developed almost within the same period. The average number of days required by the fundatrices to attain maturity was 12.4 days (Table 1), whereas Radke *et al.* (1973) observed 12.2 days in parthenogenetic viviparous nymphs to reach maturity from birth at 18.0°C, and 12 hours photoperiod per day.

The prereproductive, reproductive, postreproductive period and longevity observed in fundatrices were 1.4, 8.2, 1.2 and 10.9 days respectively. Thus longevity was considerably low in fundatrices than in the parthenogenetic viviparous females where it was observed to be 27.3 days (Radke *et al.*, 1973).

THE BODY MEASUREMENTS OF FUNDATRICES :

The body measurements of the fundatrices recorded, are presented in Table 2. Falk (1957-58) could record the morphological observations on single specimen of fundatrix. He observed the body length to be 1.97 mm, antenna 0.82 mm, siphunculata 0.23 mm, cauda 0.18 mm with 14

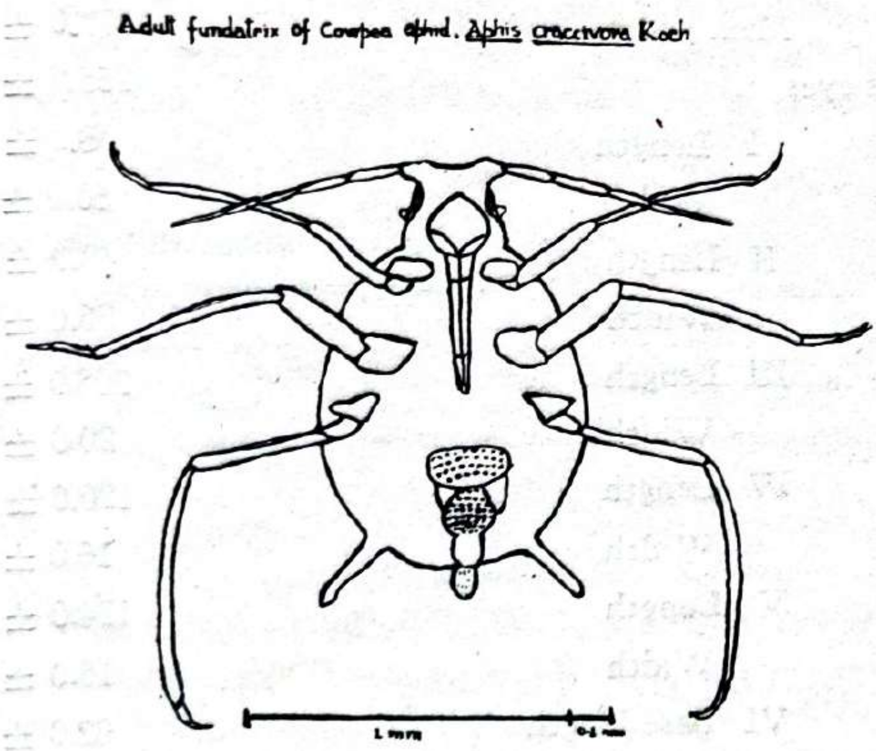

Fig. 1—Adult fundatrix of cowpea aphid, *Aphis craccivora* Koch.

hairs on genital plate and six antennal segments. The body measurements presented in Table 2 indicate the average body length to be 1232μ with body width 877μ. The length of antennal segments of the fundatrices is shorter than the antennal length observed in parthenogenetic viviparous female (Radke *et al.*, 1972). The rhinaria present on the antennal segments were similar to those observed in parthenogenetic viviparous females. There is not much difference in cornicle length of fundatrices and other forms of aphids except parthenogenetic viviparous apterous female. The caudal length does not differ much in fundatrix and in other forms of this aphid species reported by Radke *et al.* (1972). The body shape of adult fundatrix (Fig. 1) is different from that of the adult parthenogenetic viviparous female (Fig. 2).

TABLE 2

Mean measurements (μ) of various body parts of adult fundatrices of cowpea aphid, *Aphis craccivora* Koch.

Body part			Mean measurement in (μ) of adults ± SD for adult fundatrices.
Body :			*
		Length (vertex to base of cauda)	1237.0 ± 99.0
		Max. width	877.0 ± 153.0
Width across eyes			255.7 ± 10.5
Antennal segments	I	Length	48.0 ± 0.3
		Width	60.0 ± 4.0
	II	Length	48.0 ± 0.0
		Width	36.0 ± 4.6
	III	Length	208.0 ± 26.1
		Width	20.0 ± 4.6
	IV	Length	120.0 ± 9.2
		Width	16.0 ± 0.0
	V	Length	124.0 ± 16.0
		Width	16.0 ± 0.0
	VI	Base length	82.0 ± 4.0
		Width	16.0 ± 0.0

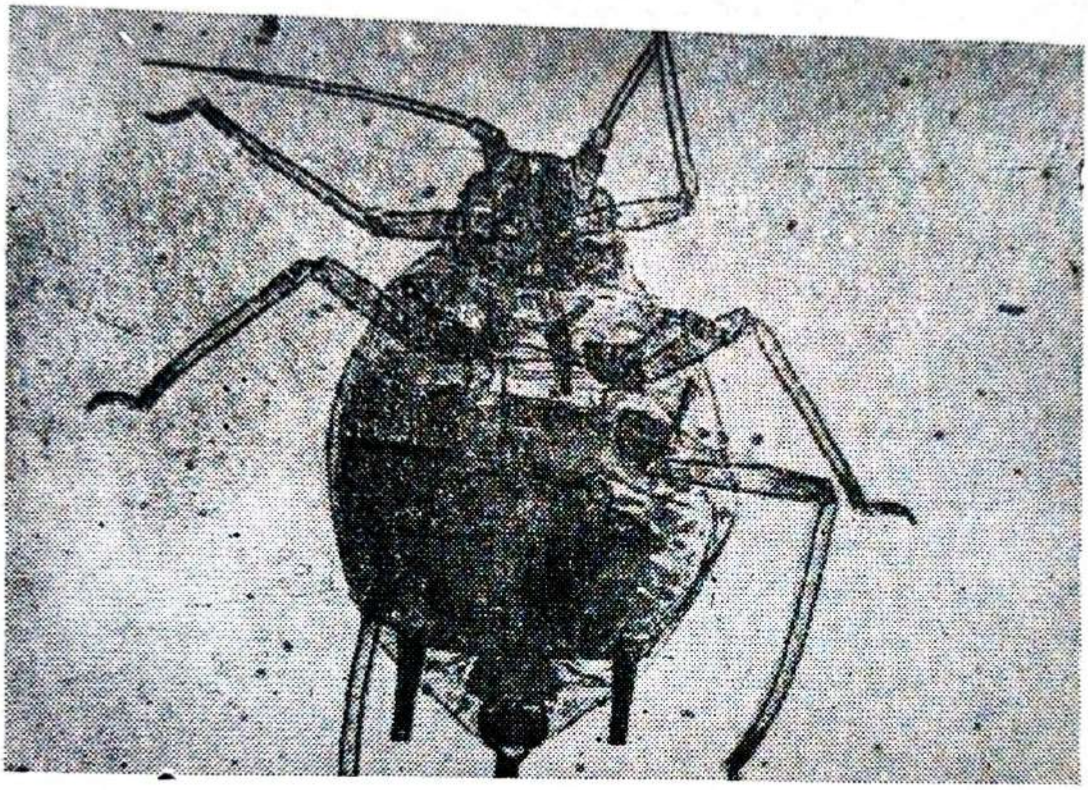

Fig. 2—Adult parthenogenetic viviparous female of cowpea aphid, *Aphis craccivora* Koch.

Table 2—(*Contd.*)

Mean mesurements (μ) of various body parts of adult fundatrices of cowpea aphid, *Aphis craccivora* Koch.

Body parts		Mean measurement in (μ) of adults ± SD for adult fundatrices.
	Processus terminalis	
	Length	184.0 ± 27.7
	Width	8.0 ± 0.0
	Primary rhinaria (Nos) 1	1.0 ± 0.0
	Secondary rhinaria (Nos) 4 to 5 Mean	4.2 ± 0.5
Hind tibia	Length	622.0 ± 0.0
	Width (mean of measurements at base, centre & apex)	34.0 ± 0.0
Hind tarsal segment		
I	Length	27.0 ± 0.0
	Width	22.0 ± 0.0
II	Length	86.0 ± 0.0
	Width	22.0 ± 0.0
Cornicle	Length at base	123.7 ± 36.0
	Width at base	55.0 ± 0.0
	centre	49.0 ± 0.0
	apex	35.0 ± 0.0
Cauda	Length	105.8 ± 0.0
	Width at base	68.0 ± 0.0

* Each observation is the mean of 4 samples examined.

REPRODUCTION

Upon reaching maturity each fundatrix reproduced by laying parthenogenetically viviparous nymphs on an average 14.55 ± 14.33 young ones. These nymphs further developed into either as alatae or apterae. Among the total progeny produced by the fundatrix, 50.38% developed as alates and 49.62% developed as apterous parthenogenetic viviparous females.

ACKNOWLEDGMENTS

The author is grateful to Dr. B. F. Coon, Head Deptt. of Entomology, the Pennsylvania State University, University Park, U. S. A. and Dr. A. W. Benton and Dr. W. G. Yendol, Professors of the same department for their valuable guidance, help and providing laboratory facilities.

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The Aphids : 117.125

DEVELOPMENT AND METAMORPHOSIS OF *MYZUS PERSICÆ* SULZER IN RELATION TO HOST PLANTS*

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ABSTRACT

Studies were carried out under glasshouse conditions on the life history of the green peach aphid *Myzus persicae* Sulzer on five different host plants. It was found that there was no variation in the duration of each stadium when reared on either brinjal, cabbage, cauliflower, chillies or tobacco and the life cycle was completed in about six days, while the longevity, fecundity and lelative growth rate (RGR) varied. Among the host plants tested, cabbage and cauliflower were observed to te the most suitable hosts as the aphid grows faster, lived longer and the reproduction rate was higher on the two hosts. Chillies and tobacco came next while brinjal did not appear to be a suitable host.

INTRODUCTION

Myzus persicae Sulzer is commonly known as green peach aphid as its primary host is peach, *Prunus persicae* L. It is also called as tobacco aphid, or spinach aphid or white aphid. It is one of the most destructive species of aphid attacking plants of ever 30 different families (David, 1954), and transmitting more than 200 virus diseases (van Emden *et al.*, 1969). Various aspects of its biology have been studied on several crops in India and abroad (Mason, 1922; Weed, 1927; De jong, 1929; Lal, 1950; Sylvester, 1954; Li *et al.*, 1963; Toba, 1964; Ramaprasad *et al.*, 1975) but no information from India is available on its performance on brinjal, chillies, cabbage and cauliflower. Studies were, therefore, taken up under glass-house conditions to compare the development and metamorphosis and fecundity of apterous *M. persicae* on the above mentioned host plants along with tobacco and the results of observations are reported hereunder.

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* **Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award for M. Sc. (Ag.) Degree.**

MATERIALS AND METHODS

Studies on the life cycle of *M. persicae* were taken up during August-September, 1977 under glasshouse conditions with mean maximum and minimum temperatures of 28°C and 18°C respectively and relative humidity of 75±5 percent. Five host plants viz., brinjal (varity S.M 50A), cabbage (September), cauliflower (Kibo Giant), chillies (K-1) and tobacco (Oosi Kappal) were used in this study. Aphids were collected from the field from the above mentioned host plants and reared on their respective host plants. Leaf clip-on cages were used to confine the individuals and study the life cycle of the aphid.

Newly born nymphs were collected by allowing the adult aptera to lay young ones on leaf discs floated in nutrient solutions and they were transferred to he leaf clip-on cages fixed on the lower surface of the leaves and covered with the lid. Twenty-five such nymphs were studied on each of the five host plants and observations were made at 12 h interval to note the development period of each instar, preoviposition period, adult longevity and fecundity.

Observations were also made to assess the relative suitability of these host plants for this aphid by measuring the relative growth rate (RGR). Weights of newly born nymphs and of those after six days of inoculation on to the host plants were taken using 'Precision Torque' monopan balance (with accuracy of 20 μg) and the RGR was calculated using the formula given by van Emden (1969) :

$$\text{Mean RGR } (\mu g / \mu g / \text{day}) = \frac{\log e \text{ final weight } (\mu g - \log e \text{ initial weight } (\mu g)}{\text{Number of days over which the increase is measured}}$$

RESULTS AND DISCUSSION

It was observed that apterous *M. persicae* underwent four nymphal instars irrespective of the host plants on which they were reared. Though there were earlier reports that this aphid underwent four to five nympal instars (Ramaprasad *et al.*,1975), in the present investigation, no such variation was noticed in the number of nymphal instars. The nymphs were either yellowish white (on brinjal, chillies and tobacco) or light greenish (on cabbage and cauliflower) in colour. The first instar nymph has five segmented antennae and the cauda is rounded. The second instar nymph is similar in appearance with that of the first instar nymph but has longer antennae which almost reach the base of the cornicle or beyond. The third and fourth instar nymphs have six-segmented antennae and there is overlapping in their size and shape. However they could be identified by the presence of exuviae inside the cage at periodical observations.

Life cycle :

The duration of the first instar ranged from 24 to 48 h and second and third instars from 24 to 60 h on different host plants (Table 1) and the mean durations were shortest on tobacco (26.88 h, 35.04 h and 35.52 h respectively) and longest on cauliflower (29.76 h, 37,44 h and 40.32 h respectively). But the duration of fourth stadium ranged from 24 to 72 h and development was quickest on brinjal (40.32h) and was prolonged on chillies (44.64 h). On an average the total development was completed in about six days with a range of 108 to 180 h. The mean nymphal period was shortest on tobacco (138.72 h) followed by brinjal (143.04 h), cabbage (147.84 h), chillies (148.32 h) and cauliflower (149.76 h). However, these variations in the duration of each stadium and the total nymphal period between host plants were found not significant. Similar results were also observed by Weed (1927) on spinach, Sylvester (1954) and Toba (1964) on mustard and Ramaprasad *et al* (1975) on tobacco. However, Lal (1950) reported nymphal period on potato to be much shorter than that observed during the present investigation which might be due to the climatic variations and host plant suitability.

Adult longevity and fecundity :

Adult apterae after last ecdysis lived significantly for longer periods of 17.04 and 16.92 days on cauliflower and cabbage respectively than on other host plants (Table 2; Fig. 1). On tobacco the longevity was the shortest (14.94 days) followed by brinjal (15.28 days) and chillies (15.70 days). Similar results were also observed by Mason (1922) on cabbage and Ramaprasad *et al* (1975) on tobacco but Weed (1927) and Sylvester (1954) reported much longer longevity of the adults, on spinach and mustard respectively while Lal (1950) and Toba (1964) reported that the adults lived for a shorter period of about 10 days only on potato and mustard. These variations might be due to the environmental variations and due to host plant nutrition factors. In the present investigation, variations were observed between host plants which can be attributed to the nutritional status of those host plants.

TABLE 1

Development and metamorphosis of apterous *Myzus persicae* on diffetent host plants.

Sl. No	Host plants	Duration of the Stadia in hours				Total development period in h
		I	II	III	IV	
1.	Brinjal	28.32 ± 2.82 (24 — 48)	35.52 ± 2.67 (24 — 48)	38.88 ± 3.28 (24 — 60)	40.32 ± 4.01 (24 — 60)	143.04 ± 5.52 (120 — 180)
2.	Cabbage	29.28 ± 3.22 (24 — 48)	39.96 ± 3.17 (24 — 48)	38.4 ± 4.29 (24 — 60)	43.2 ± 4.77 (36 — 60)	147.84 ± 6.35 (120 — 180)
3.	Cauliflower	29.76 ± 3.23 (24 — 48)	37.44 ± 3.30 (24 — 48)	40.32 ± 3.16 (24 — 60)	42.24 ± 3.24 (36 — 60)	149.76 ± 4.55 (120 — 168)
4.	Chillies	28.8 ± 3.20 (24 — 48)	36.96 ± 3.48 (24 — 60)	37.92 ± 3.09 (24 — 60)	44.64 ± 4.41 (36 — 72)	148.32 ± 6.05 (132 — 168)
5.	Tobacco	26.88 ± 2.82 (24 — 48)	35.04 ± 2.83 (24 — 48)	35.52 ± 3.91 (24 — 60)	41.28 ± 3.08 (24 — 60)	138.72 ± 6.08 (108 — 168)

(Figures in parentheses represent the range)

Comparison of significant effects	Level of significance	CD (P = 0.5)
First stadium	N. S.	—
Second stadium	N. S.	—
Third stadium	N. S.	—
Fourth stadium	N. S.	—
Total devolopment period	N. S.	—

N. S. = Non-significant.

TABLE 2

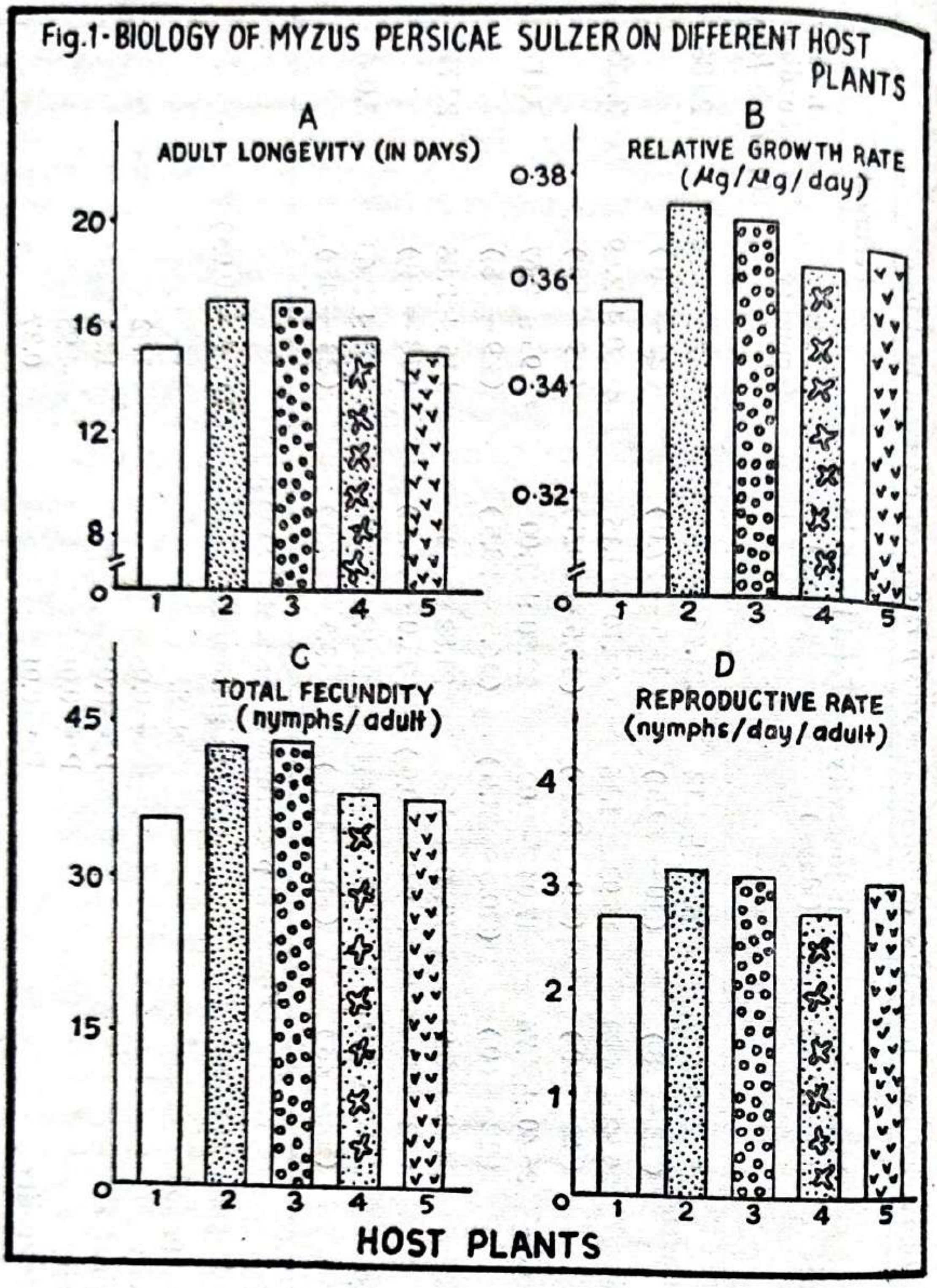
Longevity and fecundity of apterous *Myzus persicae* on different host plants.

Sl. No.	Host plants	Maturation period (h)	Adult longevity (days)	Total longevity (days)	Fecundity	
					Total fecundity	Mean daily fecundity (nymphs/day)
1.	Brinjal	25.44 ± 4.37 (12 — 48)	15.28 ± 1.12 (10 — 19.5)	21.26 ± 1.57 (16.5 — 27.0)	35.72 ± 2.79 (23 — 48)	2.686
2.	Cabbage	25.92 ± 4.89 (12 — 60)	16.92 ± 1.16 (9 — 22.5)	23.10 ± 1.16 (15.5 — 29.5)	42.60 ± 2.69 (29 — 55)	3.155
3.	Cauliflower	26.40 ± 4.74 (12 — 60)	17.04 ± 1.09 (10.5 — 21.5)	23.30 ± 1.00 (16.5 — 28.5)	42.96 ± 2.67 (29 — 56)	3.117
4.	Chillies	24.48 ± 3.91 (12 — 48)	15.70 ± 1.28 (9.0 — 20.5)	21.82 ± 1.24 (15.0 — 26.5)	38.16 ± 2.86 (18 — 49)	2.771
5.	Tobacco	24.00 ± 3.20 (12 — 48)	14.94 ± 1.61 (8 — 19.5)	20.72 ± 1.17 (13.5 — 24.5)	37.40 ± 2.63 (23 — 48)	3.056

(Figures in parentheses represent the range)

Comparison of significant effects	Level of significance	CD (P = 0.05)
Preoviposition period	N. S.	—
Adult longevity	P = 0.05	1.72
Total longevity	P = 0.01	1.58
Total fecundity	P = 0.01	4.98
Mean daily fecundity	P = 0.01	0.27

N. S. = Non significant.



HOST PLANT: (1) Brinjal; (2) Cabbage; (3) Cauliflower; (4) Chillies and (5) Tobacco.

TABLE 3

Relative Growth Rate of apterous *Myzus persicae* on different host plants.

Sl. No.	Host plants	Initial weight		Final weight after 6 days		RGR ($\mu g/\mu g$/day)
		μ g	log e μ g	μ g	log e μ g	
1.	Brinjal	19	3.6635	328	5.7931	0.356
2.	Cabbage	40	3.6888	372	5.9189	0.371
3.	Cauliflower	40	3.6888	376	5.9296	0.374
4.	Chillies	39	3.6635	346	5.8465	0.363
5.	Tobacco	40	3.6888	360	5.8861	0.367

	Level of significance	CD (P = 0.05)
Between host plants	P = 0.01	0.006

The adults started reproduction in about a day after final ecdysis and there was no significant difference in the preoviposition period between host plants. The daily reproduction was low on the first day of reproduction and reached maximum in six or seven days followed by a gradual decrease thereafter. Among the five host plants tested, cauliflower and cabbage were found to favour the reproduction of the aphid and on these host plants the aphid produced 42.96 and 42.6 young ones per female in its life time. On chillies and tobacco, individual aphids produced 38.16 and 36.4 nymphs respectively while on brinjal it produced 35.72 nymphs only. Similar variaions between the host plants were reported earlier by Heathcote (1962) on several cole crops. However, Weed (1927) and Sylvester (1954) reported a higher fecundity and Lal (1950) a lower fecundity on the respective host plants on which they had tested.

With regard to the mean daily fecundity it was more on cabbage, cauliflower and tobacco (3.16, 3.12 and 3.06 aphids/day/female respectively). Weed (1927) and Sylvester (1954) however observed a higher rate of reproduction.

Relative growth rate (RGR) :

Relative suitability of the host plants tested by using RGR as a parameter revealed that cabbage and cauliflower enable the aphid to grow faster at the rate of 0.374 and 0.370 micrograms per day followed by chillies (0.367 µg/µg day), tobacco (0.363 µg/µg day) and and brinjal (0.356 µg/µg day) (Table 3; Fig.1). This showed that cabbage and cauliflower are more suitable host plants for this aphid while brinjal is the least suitable among the five host plants, as it does not favour a quick growth of the aphid. This may be due to lack of some nutritional factors from the host plant (van Emden, 1977).

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* Original not seen.

STUDIES ON THE DEVELOPMENT AND METAMORPHOSIS OF THE GREEN PEACH APHID *Myzus persicae* SULZER BY CROSS INOCULATION AMONG DIFFERENT HOST PLANTS*

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ABSTRACT

Studies were conducted under caged conditions with the aphid clones collected from three host plants viz., brinjal, chillies and tobacco from three different localities. It was found that there was no significant difference between the clones in their ability to colonise on different host plants when cross inoculation was effected. Similarly, there was no variation in the development of this aphid on the original host plant from which it had been collected as well as their alternate host plants with reference to maturation period and total longevity. However, the fecundity of the adults varied significantly among the host plant combinations.

INTRODUCTION

Myzus persicae Sulzer is one of the most destructive species of sucking pests which gained universal attention among research workers by virtue of its increasing host range and developing resistance to several insecticides (Dunn and Kempton, 1966; Beranak, 1974; Needam and Devanshire, 1975; Baker, 1977; Blackman *et al*., 1977). Besides, development of biotypes in this aphid was also identified in recent years. Biotypes in aphids have been reported by different workers based on the criteria of morphology and colour (Brain, 1942; Tanaka, 1957; Eastop and Russel, 1967), biology and host preferences (Brain, 1942; Stanford and McMurtry, 1959; Cruz and Bernardo, 1971; Wood, 1961, 1971; Lave, 1973), virus transmitting ability (Stubbs, 1955; Williams and Ross, 1957), difference in feeding behaviour (Parry and Ford, 1967; Halimie and Ford, 1972) and difference in resistance to insecticides (Shirik, 1960; Dunn and Kempton,

* **Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M. Sc. (Ag.) Degree.**

1966; Halimie and Ford, 1972). In Tamil Nadu, this pest was found earlier only in hilly regions and later spread to plains attacking only tobacco. But in recent years it has been found damaging chillies, brinjal and even 'bhendi' and control of the pest has proved to be difficult. Hence a study was made to identify the presence of biotypes, if any, among the clones that attack chillies, brinjal and tobacco and the results of observations are reported in this paper.

MATERIALS AND METHODS

The biotype studies were restricted to clones collected from the plains of Tami Nadu. The clones included were those collected on brinjal, chillies and tobacco from Palladam, Coimbatore and Sathiamangalam areas respectively. The clones collected from these areas were maintained on their respective host plants for six to eight generations and later transferred to other alternate host plants kept isolated from each other by means of iron ring cages to cover the plants.

Newly born nymphs were collected by allowing individual aphids to lay young ones on a confined leaf, and their life cycle was studied on all the three original host plants from which they were collected and on the other alternate host plants on which they were subsequently cross-inoculated. Individual first instar nymphs were confined in leaf clip-on cage and observations were made at 12 h interval to record information on metamorphosis and development, pre-oviposition period, longevity and fecundity of adults.

RESULTS AND DISCUSSION

The data on the differences found in the biology of the aphid species and its ability to develop on the cross inoculation host plants viz, brinjal, chillies and tobacco are given in Tables 1 and 2.

Colonisation :

Present studies conducted under caged conditions showed that the aphid clones collected from any one of the three host prants viz., brinjal, chillies and tobacco were capable of colonising the other two host plants. Studies carried out by Lowe (1973) showed that due to some biotypical differences ***M. perscicae*** colonising sugarbeet failed to establish on Chinese cabbage and broadbeans. Similar results of such inability was also reported by Harvey and Hackerott (1969) among the green bug, ***Schiaphis graminum*** R., infesting sorghum.

Development and metamorphosis :

Except for the duration of the fourth stadium and total developmental period, there was no significant variation in the development of these clones on their original as well as alternate host plants under all combinations. The aphids collected from and reared on the original host plant completed the fourth stadium quicker than when reared on the other two alternate host plants. The duration of the fourth stadium was shortest on tobacco irrespective of whether it was the original host plant and was prolonged on other hosts. Also, there was no significant difference between the duratian of the fourth stadium of a clone on the original as well as alternate host plants except for the clone from tobacco for which the duration was considerably prolonged on brinjal. These little variations are negligible when compared with other aphid biotypes like alfalfa aphid, *Therioaphis maculata* B., where some clones even failed to complete the development on a resistant variety while an another clone could develop and reproduce well (Pesho and Lieberman, 1960).

TABLE 1

Variation in development and metamorphosis *M. persicae* due to cross inoculation to other host plants.

Sl. No.	Host plants (Treatments)	Duration of Stadia in h.				Total nymphal period in h.
		I	II	III	IV	
1,	Brinjal to brinjal	28.32	35.52	38.88	40.32	143.04
2.	Brinjal to chillies	29.76	37.44	39.36	45.12	151.68
3.	Brinjal to tobacco	27.44	36.48	36.96	40.80	142.08
4.	Chillies to brinjal	29.28	38.40	39.84	48.48	156.00
5.	Chillies to chillies	28.80	36.96	37.92	44.64	148.32
6.	Chillies to tobacco	28.32	36.48	36.48	45.60	144.96
7.	Tobacco to brinjal	28.80	37.44	37.92	49.44	153.60
8.	Tobacco to chillies	30.24	36.00	38.40	48.00	152.64
9.	Tobacco to tobacco	26.88	35.04	35.52	41.28	138.72
Level of significance		N.S	N.S	N.S	P=0.50	P=0.01
CD (P = 0.05)		—	—	—	5.89	9.03

TABLE 2

Variation in adult longevity and fecundity of *M. persicae* due to cross inoculation to other host plants

Sl. No.	Host plants	Matuaation period (h)	Adult longevity (days)	Total longevity (days)	Total fecundity (nymphs/female)
1.	Brinjal to brinjal	25.44	15.28	21.26	35.72
2.	Brinjal to chillies	26.40	14.26	20.58	37.04
3.	Brinjal to tobacco	24.96	13.86	19.78	32.56
4.	Chillies to brinjal	26.88	14.44	20.94	35.28
5.	Chillies to chillies	24.48	15.70	21.88	38.16
6.	Chillies to tobacco	24.96	13.26	19.30	34.44
7.	Tobacco to brinjal	25.92	14.00	20.38	34.40
8.	Tobacco to chillies	25.92	15.38	21.70	37.04
9.	Tobacco to tobacco	24.00	14.94	20.70	37.40
Level of significance		N.S.	N.S.	N.S.	P = 0.05
CD (P = 0.05)		—	—	—	3.41

***Adult longevity and fecundity*:**

There was no significant difference in the longevity of the adults but fecundity differed significantly between host plants under different combinations. The fecundity was lowest on tobacco for the clones collected from brinjal (38.16 nymphs/adults) and was highest for those collected from and reared on chillies. The reproductivity of all the three clones was low and was on par with each other on brinjal and was high and on par as well on chillies. Spectacular differences were reported by Pesho and Lieberman (1960) in the alfalfa aphid where a biotype produced 110 young on a resistant variety of sorghum as against no reproduction in two days by an another biotype. Cartier and Painter (1956) and Wood (1971) also reported similar variations among the biotypes in the aphids. The results obtained in the present studies revealed that fecundity is reduced in *M. persicae* when there is a change in the host plant.

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* Original not seen.

STUDIES ON THE EMBRYONIC DEVELOPMENT IN THE COMMON MAIZE APHID *RHOPALOSIPHUM MAIDIS* (FITCH)

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ABSTRACT

Seven different stages of embryo can be differentiated in *Rhopalosiphum maidis* (Fitch). The alimentary canal is formed in the fifth stage and the segmentation of the body takes place in the sixth stage embryo. The seventh or the final stage embryo is laterally flattened and the different parts of the body viz., head, thorax, abdomen, antennae and legs become prominent. The duration of different stages of embryo at laboratory temperature 25 ± 3.5°C and 68% mean relative humidity, is as follows: second stage, 22 to 28 hours; third stage, 4 to 7 hours; fourth stage, 5 hours; fifth stage, 8 hours; sixth stage, 17 to 21 hours, and final stage, approximately 9 hours. The first (egg) and the second stage embryos appear in the third nymphal instar of the aphid species.

INTRODUCTION

The embryology of insects finds adequate description in standard works on the subject (Snodgrass, 1935; Imms, 1957; Wigglesworth, 1965 and Anderson, 1972). However, there occur few specific references to the study of embryonic stages of aphids. Behrendt (1963) has given a description of the winter egg of *Aphis fabae* Scopoli. Mayo and Starks (1972) studied the embryonic stages by cytological staining and divided the embryos of the green bug roughly into three sizes. Elliott *et al* (1975, 1976) have described 9 embryonic stages of *Aphis craccivora* Koch.

The present study deals with the morphology of the different stages of the embryo of the maize aphid, *Rhopalosiphum maidis* (Fitch.).

MATERIALS AND METHODS

Specimens of apterous and alate viviparous morphs of *R. maidis* were collected on *Zea mays*. For preparation of slides of embryos aphids were killed in warm water and placed on a clean slide smeared with egg albumen, in a drop of distilled water. The embryos were extracted by opening the abdomen of the specimens. The water on the slides were allowed to evaporate taking care to see that the material did not shrivel up. Harris haematoxylin was used to stain the embryos after which the slides were passed through different grades of alcohol and mounted in D. P. X. This method was found to be the best for the study of embryos of all the stages.

To note the first appearance and development of the embryos through different instars and adults, and to calculate the duration of different embryonic stages, *R. maidis* was reared in the laboratory on maize at 25 ± 3.2°C and 68% mean relative humidity.

RESULTS AND DISCUSSION

Developmental stages :

The embryos of *Rhopalasiphum maidis* can be coveniently divided into the following categories according to their size and structure. Elliott and McDonald (1976) described the egg of *Aphis craccivora* Koch., as the first stage embryo and the terminology has been retained by us.

a) First stage embryo (egg or the oocyte)

b) Second stage embryo

c) Third stage embryo

d) Fourth stage embryo

e) Fifth stage embryo

f) Sixth stage embryo

g) Final stage embryo.

A. *First stage embryo* (Figs. 1 A and B) :

The immature egg (oocyte) is ovoid. The immature round eggs can be distinguished from the plasmatocytes of the haemolymph by the presence of a large quantity of yolk and larger size. The mature eggs are flattened dorsally with a centrally placed nucleus and the cytoplasm is filled with yolk. The egg is covered with two membranes, the outer, the vitelline membrane and the inner, the chorion. This stage resembles the first stage embryo of *Aphis craccivora* (Elliot and Mc Donald, 1976). The mean diameter of the immature egg is 0.015 ± 0.002 mm ranging from 0 012 to 0.016 mm (Table 1). The mature egg is slightly larger than the immature egg, containing a single nucleus. In the fertilized egg of the insects, at the anterior end, the chorion is perforated by a minute opening, the micropyle, which permits the entrance of the spermatozoon (Snodgrass, 1935). In the egg of *R. maidis* no such minute opening is noticed.

B. *Second stage embryo* (Fig. 1 C):

The nucleus of the egg divides superficially in a syncytial manner to form the second stage embryo. The second stage embryo is a thin jelly-like mass and is covered by the membranes mentioned earlier. This stage resembles the second stage embryo of *A. craccivora* (Elliott and Mc Donald, 1976). The length of the second stage embryo ranges from 0.064 to 0.128 mm with a mean of 0.089 ± 0.019 mm and the breatdh ranges from 0.032 to 0.088 mm with a mean of 0.052 ± 0 016 mm.

C. *Third stage embryo* (Fig. 1 D):

The embryo of this stage is oval, flattened and jelly-like. In this stage a part of the blastoderm becomes more densely packed, while the remainder is attenuated over the surface of the yolk mass. The densely packed cells constitute the embryonic primordium. The more attenuated cells form the extra-embryonic ectoderm. This stage resembles the third stage embryo of *A. craccivora* (Elliott and McDonald, 1976). The length and breadth of the third stge embryo is 0.148 ± 0.020 mm and 0.078 ±0.019 mm respectively (Table 1). Thus early development in *R. maidis* is similar to that of other insects.

D. *Fourth stage embryo* (Fig. 1 E, Plate 1):

In this stage the embryo is also jelly-like, oval and flattened. The embryonic primordium increases in length and represents the germ band (Anderson, 1972). In the middle of the embryo there is a tube like demarkation of cells which in later stage gives rise to the alimentary canal. The mean length and breadth of the fourth stage embryo are 0.211 ± 0.028 mm and 0.136 ± 0.011 mm respectively (Table 1).

E. *Fifth stages embryo* (Fig. 1 F, Plate 2):

As the embryo develops, there is further development of the alimentary canal. The alimentary canal runs straight end to end through the middle region of the body. After running one third the length from the cephalic end it is twisted once, then runs straight to the posterior end. The eye spots become conspicuous and they appear to be connected with

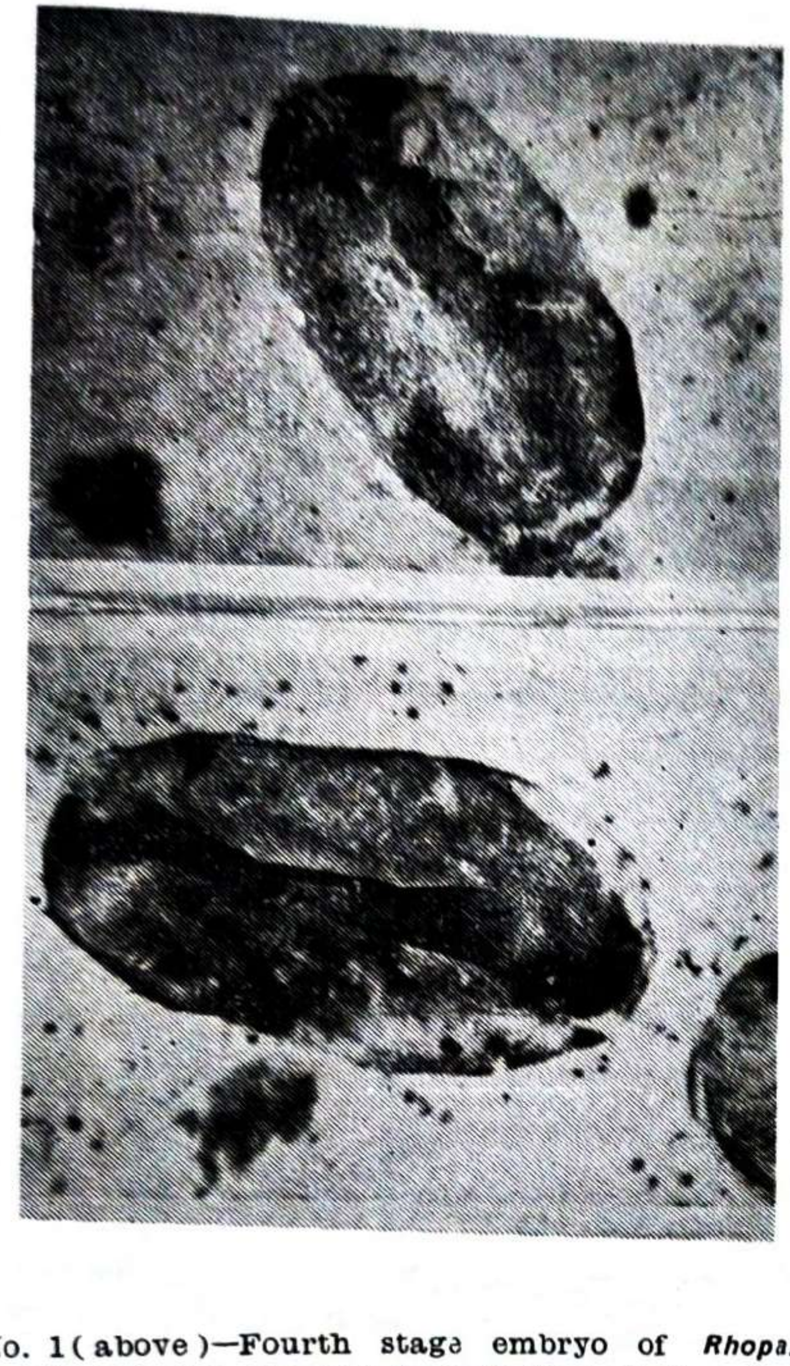

Plate No. 1 (above)—Fourth stage embryo of ***Rhopalosiphum maidis*** (Fitch) showing demarkation of alimentary canal by the aggregation of cells in the centre of the body.

Plate No. 2 (below)—Fifth stage embryo of ***Rhopalosiphum maidis*** (Fitch) showing formation of alimentary canal and eye spots.

nerves. In the anterior region, posterior to the eye spots, a slight lateral depression appears, which demarkates the head from the abdomen. The embryo at this stage is bilaterally symmetrical. The mean inter-orbital distance (distance between the two eye spots) is 0.096 ± 0.016 mm. The mean length and breadth of this stage embryo are the same as that of the third stage embryo.

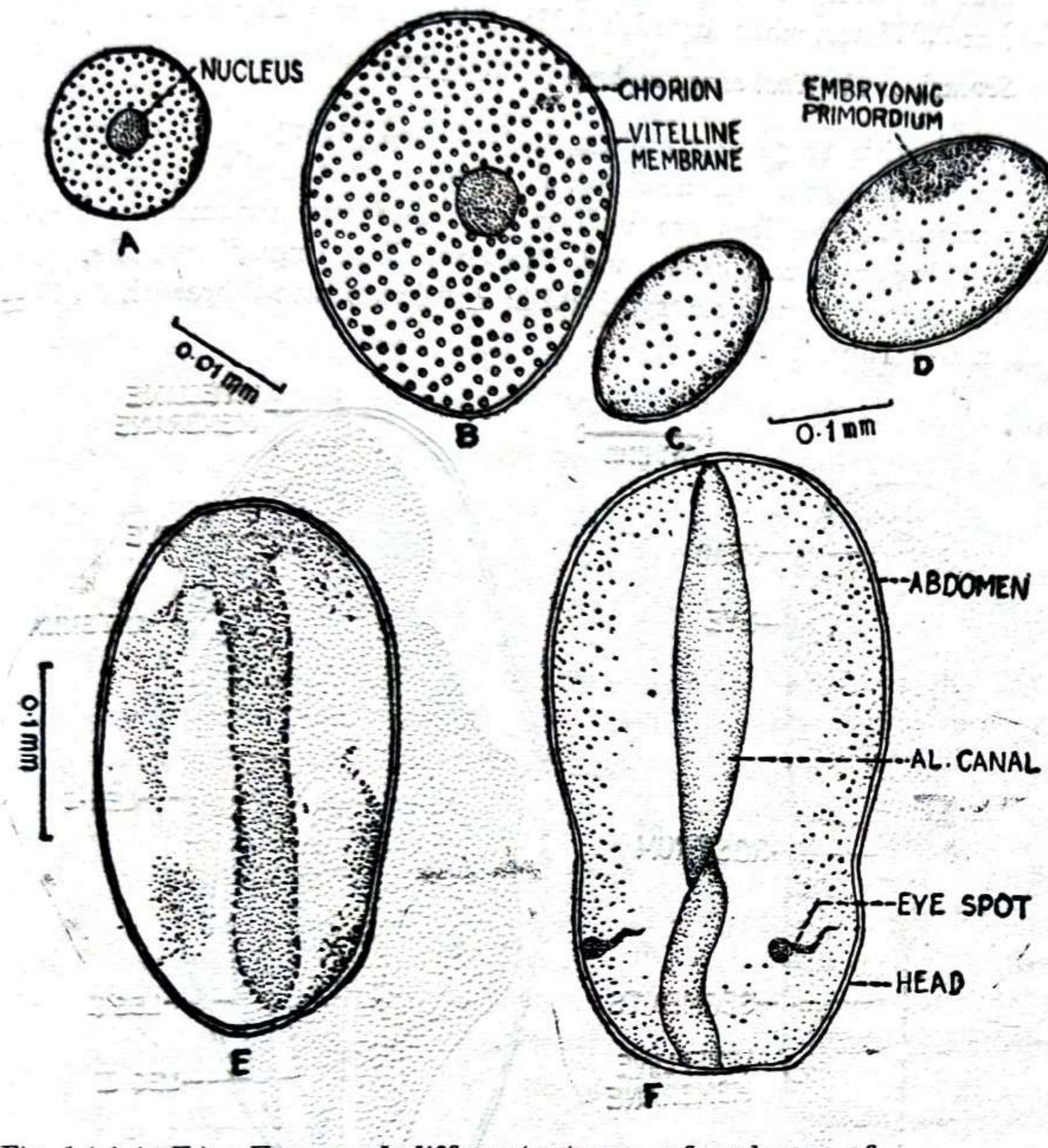

Fig. 1-(A to F)— Eggs and different stages of embryos of *Rhopalosiphum maidis* (Fitch):

A and B — First stage embryo (A — immature egg and B — mature viviparous egg)
C — Second stage embryo, D — Third stage embryo,
E — Fourth stage embryo, F — Fifth stage embryo,

F. ***Sixth stage embryo*** **(Fig. 1 G) :**

In this stage the embryo is depressed or dorsoventrally flattened. The two eyes are more prominent and occupy the two sides of the cephalic region. The trail of the eye spots appearing as connecting nerves in the fourth stage is no longer visible. Four to six abdominal segments are discernible, but not fully developed. The rostrum is also formed. Bilateral summetry is well marked. The mean length of the embryo is 0.218 ± 0.027 mm, mean breadth 0.081 ± 0.018 mm (Table 1).

G. ***Seventh or the final stage embryo*** **(Fig. 1 H) :**

In this stage the embryo is flattened laterally or compressed. It increases in length, the head becomes prominent and the antennae are differentiated. The legs are well marked and the abdomen is clearly visible. However, the cauda and the cornicle are not discernible. The length of the final stage embryo is 0.242 ± 0.024 mm and breadth 0.093 ± 0.012 mm (Table 1).

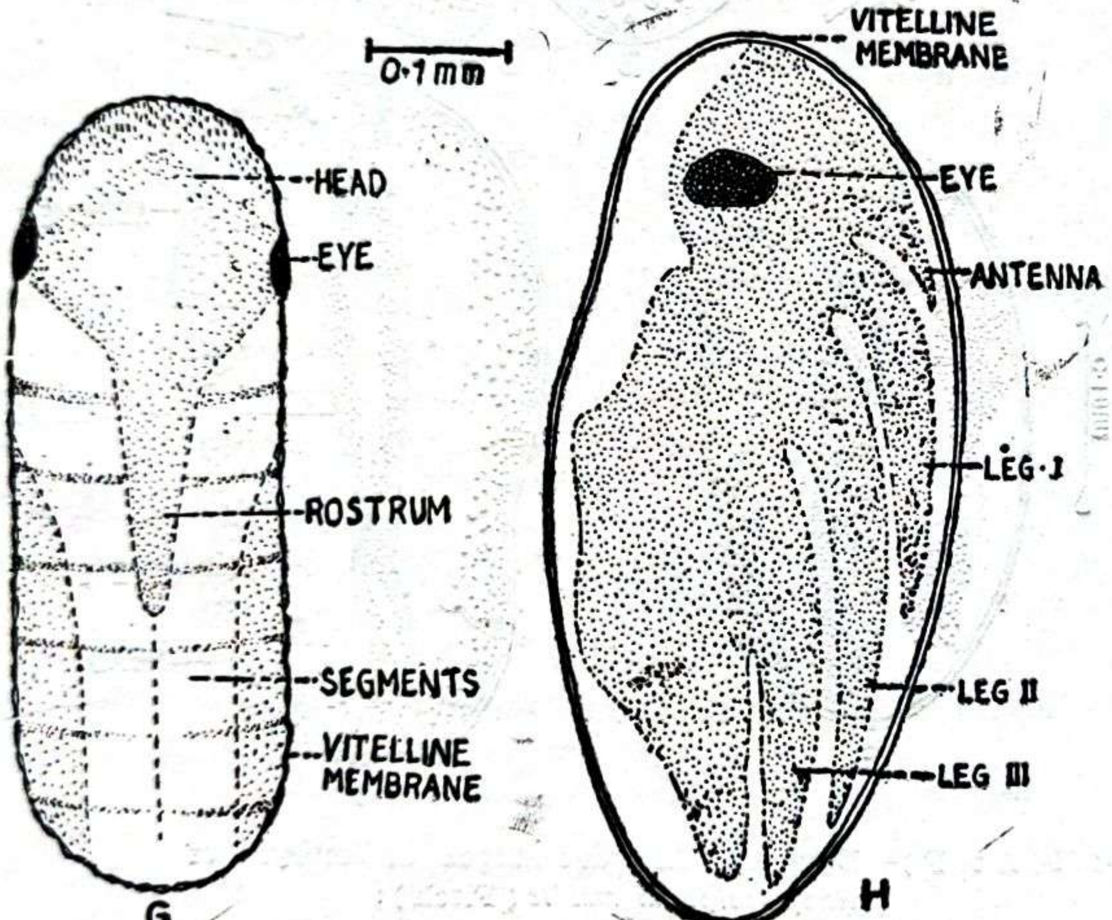

Fig. 1-(G to H)— Different embryonic stages of *Rhopalosiphum maidis* (Fitch) :

G — Sixth stage embryo, H — Seventh or the final stage embryo (shortly before hatching).

TABLE 1

Measurements of different stages of egg and embryos of *Rhopalosiphum maidis* (Fitch)

No. of obsn.	1st stage egg (oocyt) diameter in mm.	2nd stage embryo		3rd stage embryo		4th stage embryo		5th stage only inter-orbital distance in mm.	6th stage embryo		7th stage embryo	
		Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.		Length in mm.	Breadth in mm.	Length in mm.	Breadth in mm.
1.	0.016	0.088	0.056	0.144	0.096	0.240	0.152	0.108	0.256	0.104	0.252	0.100
2.	0.012	0.096	0.048	0.152	0.096	0.248	0.148	0.112	0.240	0.096	0.240	0.096
3.	0.012	0.068	0.040	0.160	0.104	0.244	0.148	0.104	0.200	0.080	0.224	0.080
4.	0.012	0.120	0.064	0.192	0.080	0.224	0.132	0.096	0.240	0.080	0.256	0.104
5.	0.020	0.080	0.044	0.176	0.080	0.240	0.120	0.096	0.144	0.048	0.262	0.108
6.	0.016	0.064	0.032	0.160	0.080	0.160	0.124	0.056	0.240	0.080	0.256	0.100
7.	0.012	0.096	0.064	0.128	0.064	0.192	0.132	0.064	0.224	0.112	0.256	0.092
8.	0.012	0.112	0.080	0.128	0.072	0.200	0.124	0.096	0.240	0.080	0.248	0.068
9.	0.016	0.096	0.040	0.120	0.080	0.192	0.136	0.068	0.176	0.056	0.192	0.076
10.	0.112	0.080	0.040	0.160	0.104	0.244	0.152	0.112	0.200	0.076	0.236	0.088
11.	0.016	0.104	0.044	0.136	0.088	0.232	0.148	0.108	0.260	0.100	0.256	0.096
12.	0.012	0.128	0.088	0.144	0.088	0.236	0.152	0.108	0.244	0.088	0.248	0.100

Table 1—(*Cantd.*)

Measurements of different stages of egg and embryos of ***Rhopalosiphum maidis*** (Fitch)

No. of obsn.	1st stage egg (oocyt) diameter in mm.	2nd stage embryo Length in mm.	2nd stage embryo Breadth in mm.	3rd stage embryo Length in mm.	3rd stage embryo Breadth in mm.	4th stage embryo Length in mm.	4th stage embryo Breadth in mm.	5th stage only inter-orbital distance in mm.	6th stage embryo Length in mm.	6th stage embryo Breadth in mm.	7th stage embryo Length in mm.	7th stage embryo Breadth in mm.
13.	0.012	0.096	0.044	0.152	0.096	0.232	0.140	0.108	0.208	0.088	0.228	0.088
14.	0.016	0.064	0.032	0.176	0.080	0.224	0.140	0.104	0.232	0.108	0.264	0.108
15.	0.016	0.056	0.036	0.168	0.088	0.220	0.132	0.108	0.152	0.048	0.266	0.108
16.	0.012	0.088	0.056	0.152	0.088	0.196	0.132	0.104	0.244	0.088	0.264	0.100
17.	0.016	0.088	0.056	0.120	0.044	0.168	0.132	0.104	0.228	0.088	0.256	0.104
18.	0.012	0.096	0.064	0.128	0.048	0.172	0.116	0.096	0.248	0.076	0.252	0.096
19.	0.012	0.112	0.080	0.116	0.044	0.176	0.116	0.080	0.192	0.060	0.192	0.076
20.	0.012	0.064	0.032	0.152	0.048	0.192	0.132	0.096	0.204	0.072	0.192	0.072
Mean	0.015	0.089	0.052	0.148	0.078	0.211	0.136	0.096	0.218	0.081	0.242	0.093
	±0.002	±0.019	±0.016	±0.020	±0.019	±0.028	±0.011	±0.016	±0.027	±0.018	±0.024	±0.012

H. Growth :

The growth of the embryo is exponential upto the fourth stage and then levels off (Fig. 2). The reduction in breadth after stage 4 is due to the formation of organs and lateral depressions demarkating different segments of the body (Fig. 2).

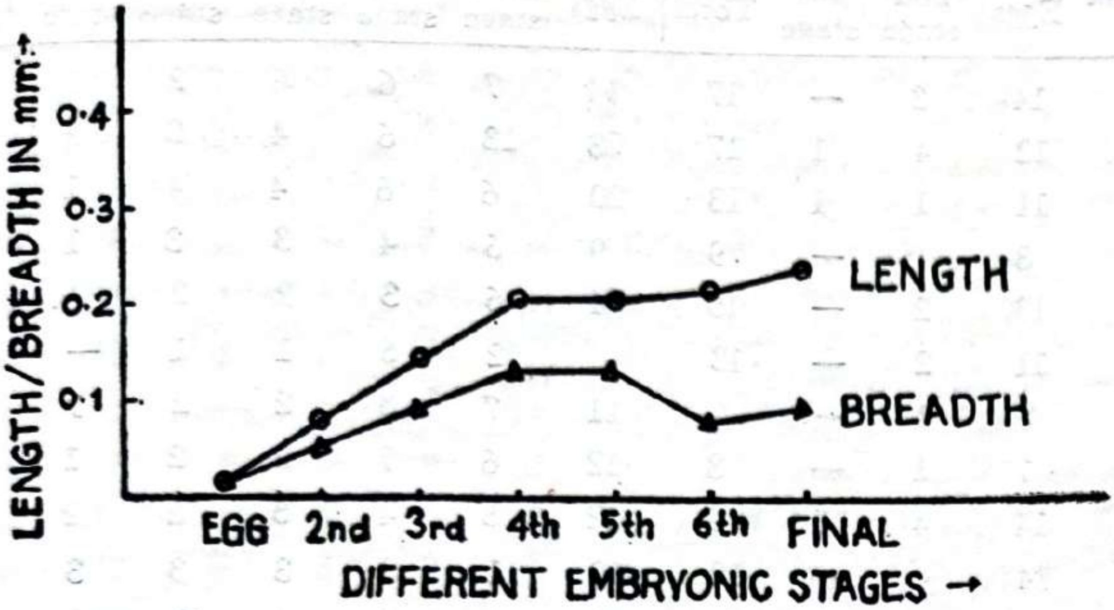

Fig. 2

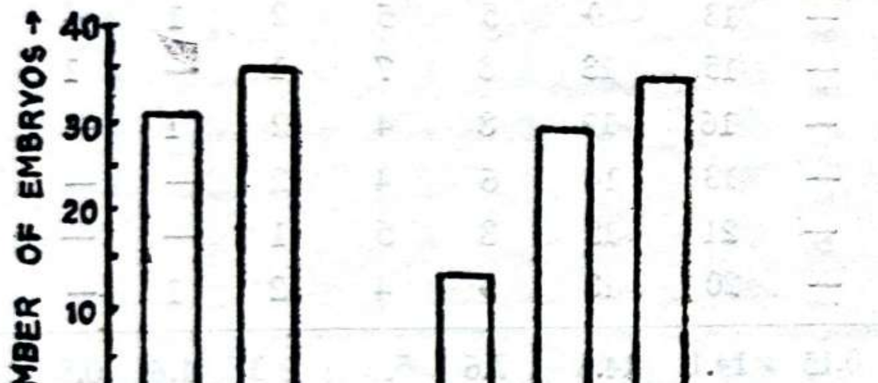

Fig. 3

Fig. 2—Graph showing growth in length and breadth in different stages of embryos of ***Rhopalosiphum maidis*** (Fitch).

Fig. 3—Histogram showing number of embryos present in different nymphal instars and adult aphids of ***Rhopalosiphum maidis*** (Fitch).

TABLE

Number of different stage embryos occurring in different

No. of obsn.	Third instar nymph Eggs	2nd stage	3rd stage	Total	Fourth instar nymph (apterous) Eggs	2nd stage	3rd stage	4th stage	5th stage	6th stage	Total
1.	14	3	—	17	14	7	6	6	2	1	36
2.	12	4	1	17	23	13	6	4	3	2	51
3.	11	1	1	13	20	6	6	4	4	1	41
4.	8	1	—	9	9	6	4	3	3	1	26
5.	13	2	—	15	14	6	3	2	2	1	28
6.	11	2	—	13	24	12	6	1	1	—	44
7.	6	1	—	7	11	7	8	2	2	1	31
8.	7	1	—	8	12	6	7	2	2	1	30
9.	14	4	1	19	12	8	4	3	2	2	31
10.	14	4	—	18	22	11	8	3	3	3	50
11.	17	3	—	20	12	9	6	1	1	—	29
12.	9	1	—	10	20	8	6	2	2	1	39
13.	6	1	—	7	14	6	4	1	1	1	27
14.	11	2	—	13	12	4	3	3	1	—	23
15.	12	1	—	13	9	5	5	2	1	—	22
16.	13	2	—	15	13	8	7	1	—	1	30
17.	14	2	—	16	12	8	4	2	1	—	27
18.	12	1	—	13	14	6	4	2	—	—	26
19.	18	3	—	21	12	8	5	1	—	—	26
20.	17	3	—	20	13	9	4	2	1	—	29
Mean	11.9	2.1	0.15	14.1	14.6	7.6	5.5	2.3	1.6	0.8	19.9

2

nymphal instars of ***Rhopalosiphum maidis*** (Fitch)

Apterous adult							
Eggs	2nd stage	3rd stage	4th stage	5th stage	6th stage	Final stage	Total
14	10	8	6	4	3	1	46
15	12	8	6	4	3	—	48
12	8	7	5	4	3	—	39
8	6	6	2	3	2	2	29
9	6	7	4	3	1	—	30
16	10	8	3	4	2	—	43
10	7	4	6	3	1	3	34
10	7	4	5	3	3	1	33
20	11	12	4	4	3	—	54
17	12	8	3	3	1	—	44
18	12	8	6	4	—	—	50
12	7	4	2	4	2	—	31
13	6	5	7	3	1	2	37
11	6	4	8	4	2	—	35
8	3	2	2	3	2	—	20
7	4	2	1	4	3	1	22
16	8	3	4	4	3	—	38
12	8	6	3	2	2	1	34
13	4	2	2	3	1	—	25
12	6	1	2	3	2	—	26
12.6	7.6	5.4	4	3.4	2.1	0.51	35.8

TABLE

Number of different stage embryos present in fourth instar

No. of obsn.	Fourth instar						
	Eggs	2nd stage	3rd stage	4th stage	5th stage	6th stage	Total
1.	14	12	8	7	2	1	34
2.	10	7	5	4	2	1	39
3.	14	6	4	2	1	—	27
4.	21	12	11	4	3	—	61
5.	20	8	9	6	2	1	46
6.	9	8	2	1	2	1	23
7.	13	6	5	2	1	—	27
8.	11	7	6	4	2	1	31
9.	12	8	4	1	2	1	28
10.	11	7	4	2	1	1	26
11.	6	2	1	1	—	—	10
12.	1	4	2	1	1	—	20
13.	24	6	2	1	1	—	34
14.	9	6	4	2	1	1	23
15.	12	6	2	4	2	1	27
16.	20	6	7	6	4	—	43
17.	23	3	2	1	1	—	30
18.	24	1	5	2	1	—	33
19.	20	9	8	6	2	1	46
20.	22	11	8	6	2	1	50
Mean	15.3	6.7	4.9	3.1	1.6	0.5	31.2

2–(*Contd.*)

alate and adult alate morphs of *Rhopalosiphum maidis* (Fitch).

Adult							
Eggs	2nd stage	3rd stage	4th stage	5th stage	6th stage	Final stage	Total
18	12	8	6	4	2	—	50
13	7	5	7	3	1	—	36
9	4	3	2	3	2	—	23
9	5	3	1	5	2	—	26
11	6	8	4	4	3	—	36
13	8	8	5	3	1	—	38
14	7	3	4	4	3	1	36
10	6	6	3	2	2	2	31
14	4	3	2	2	—	—	25
13	6	3	2	2	1	1	28
18	12	7	3	3	1	—	50
14	10	8	3	2	1	—	38
12	9	12	4	4	3	—	44
11	7	4	5	3	3	—	33
12	8	6	4	3	1	1	35
16	10	8	4	3	2	—	43
10	7	6	4	3	1	1	34
14	8	8	6	4	3	—	43
14	12	8	6	4	3	—	43
8	6	6	2	3	2	—	27
12.6	7.7	6.1	3.9	3.2	1.8	0.35	36.5

Mode of parturition :

In the ovariole of the aphid species the final stage embryo is found in the last ovarian follicle with the head towards the apex and the abdomen towards the base of the follicle. Consequently the abdomen of of the nymph comes out first and the head last at the time of parturition.

In order to deposit a nymph, usually the aphid lowers its abdomen towards the leaf surface of the host plant. The nymph emerges by bursting its embryonic membranes and grips the leaf. The mother aphid then raises its abdomen leaving the nymph behind. In rare cases the nymph was found to be dead when extruded. In such cases, the dead nymphs were always found to have failed to break open the embryonic membranes. Similar observations have been recorded by Frazer (1972) in ***Aphis fabae*** and *Acyrthosiphon* ***pisum*** (Harris).

Duration and appearance :

The duration of different embryonic stages of *R.* ***maidis*** reared in laboratory temperature of 25 ± 3.5°C and 68% relative humidity was as follows : second stage, 22 to 28 hours; third stage, 4 to 7 hours; fourth stage, 5 hours; fifth stage, 9 hours; and the duration of the total embryonic period was 65 to 78 hours.

The duration of different nymphal instars of *R. maidis* at 23°±3° C laboratory temperature and 65% relative humidity was as follows : first instar, 32.5 hours; second instar, 31.5 hours; third instar, 32 hours; fourth instar, 36 hours; (total nymphal period 5.45 days) and that of the pre-reproductive period was 11 hours (Behura and Dash, 1977).

The oocyte and the second stage embryo appear in the third instar nymph (Table 2). Elliot and McDonad (1976), however, noticed embryonic stages in the first instar nymph of *A. craccivora.* The appearance and duration of the different developmental stages of the embryos were correlated with the duration of different nymphal instars. The second stage embryo appears after 4 to 10 hours of the second moult and as the third stage embryos were found just after the third moult, it is presumed that the second stage embryos take 22 to 28 hours to give rise to the third stage embryos. The fourth stage embryos appear in the fourth instar nymphs within 4 to 7 hours of moulting. So the third stage embryos take 4 to 7 hours to develop into the fourth stage. The fifth stage embryos were found in the fifth instar nymphs within 9 to 13 hours after the third moult. So the fourth stage embryos take nearly 5 hours to reach the fifth stage. The sixth stage embryos were found in the fourth instar nymph after 17 to 21 hours of the third moult. So the duration of the fifth stage embryo to reach the sixth stage must be approximately 8 hours. The seventh or the final stage embryos are found in the ovarioles of the adults only two hours after the fourth moult. Hence the sixth stage embryos take 17 to 21 hours to reach the final stage. The adult aphids start laying nearly 11 hours after their last nymphal instar. Hence the final stage embryos take nearly 9 hours to be born as the first instar nymphs.

Number of embryos found in different nymphal instars :

The number of oocytes and different stages of embryos found in the different nymphal instars and the adults of the aphid species are presented in Fig. 3. Elliot and McDonald (1976) reported that in *Aphis craccivora* apterae contained more number of embryos than alatae. But in *Rhopolosiphum maidis*, the alate morphs were found to contain more number of embryos than the apterous morphs (Table 2).

ACKNOWLEDGMENTS

The authors wish to express their gratefulness to Dr. (Mrs.) P. Mohanty-Hejmadi of the Department for her kind collaboration.

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The Aphids : 147-159

IV. CYTOLOGY

CHROMOSOMES OF APHIDS

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There has been much work done on the cytogenetics of insects and the use of cytogenetics in insect taxonomy. This work has been reviewed by White (1954, 1956a, b), Smith (1960), and Boyes (1965). The greatest amount of research on insect chromosomes appears to have occurred in the order Diptera, especially with *Drosophila*, but work on the order Homoptera and the family Aphididae has been in progress for over 70 years.

Early work on aphids and phylloxerans was done by Stevens (1905-1909), Tannreuther (1907), Baehr (1908-1912), Morgan (1909-1915), and Honda (1921). Later work was done by Shinji (1923, 1931), Schwartz (1932), Jeffery (1933), Suomalainen (1933, 1943), Lawson (1936) and Ris (1942).

Recently work has been done in Canada by Dionne and Spicer (1957), MacDonald and Harper (1965), Sun (1965), Harper and MacDonald (1966, 1968), Sun and Robinson (1966), Chen (1968), Robinson and Chen (1969); in Great Britain by Colling (1955), Blackman (1971-1978); in Holland by Gut (1976); in India by Sethi and Nagaich (1972); Misra and Parida (1975); in Italy by Boshetti (1963), Cognetti (1961a, b), Cognetti and Cognetti (1961), Paglai (1961-1966), Orlando (1966-1974); in United States by Fox (1956, 1957), Olive (1967); in USSR by Kuznetsova (1968-1975), Rukavishnikov (1972), Kuznetsova and Shaposhnikov (1973). Steffan (1967-1969) working in Germany published on the chromosomes of the Adelgidae.

The cytology and cytotaxonomy of aphids was neglected for many years because of a lack of a quick, simple technique for preparing the specimens for study. The earlier workers used sectioned material that took considerable time to prepare. Most of the scientists working in the last 20-25 years have used squash techniques. Colling (1955) fixed smears of aphids in osmic acid and stained them with crystal violet. Dionne and Spicer (1956) stained them with Gomori's hematoxlin. MacDonald and Harper (1965) developed a rapid Feulgen squash method that was quick and simple. Accurate chromosome counts and excellent mitotic figures could be obtained 30 minutes after the removal of the embryos from the live aphids. Olive (1967), Kuznetsova (1968), and Sun and Robinson (1966) used an aceto-orcein method and the latter also used a modification of the Feulgen squash technique. Later workers have used similar methods and most papers give detailed information on the method used.

In studying aphid chromosomes, embryos from freshly collected apterous aphids should be used as those from aphids stored in the laboratory overnight have fewer mitotic divisions. The adult body and the larger embryos should be discarded and 3 or 4 small embryos put on a slide. Kuznetsova (1968) found in his studies that the smallest embryos from 4th and 5th instar larvae were most suitable. Winged forms usually have embryos with few mitotic divisions and much fat body but good preparations can be obtained by using small embryos from nymphs with wing buds. At present there does not seem to be a suitable fixative for preserving aphids so that the chromosomes can be examined at a later date. General information on techniques for handling and studying insect chromosomes is given by Smith (1942, 1960) and Darlington and La Cour (1950).

Smith (1960) points out that aphid chromosomes lack a centromere and are considered to be polycentric or to have a diffused centromere so that the kinetic activity is diffused over the entire length of the chromosome. Kuznetsova (1974), however, found constrictions in chromosomes of some aphids that he thought could be considered as secondary or kinetic structures, but this hasn't been reported by others. White (1954) pointed out that the chromosomes of other Homoptera, Hemiptera, and Lepidoptera also lack a typical centromere. Because the aphid chromosomes have a diffuse centromere the evolution of the karyotypes may take place by fragmentation (Kuznetsova 1968) and coalescence (Steffan 1968).

Mitotic cell division of aphids is basically similar to that of other organisms, with some differences at the metaphase. Sun and Robinson (1966) made detailed observations on the somatic cell division of the pea aphid, *Acyrthosiphon pisum* Harris, and found that these observations were similar for all other aphid species they studied. They noted that at interphase the cells show little or no definable structure and prophase is initiated at the moment when the chromosomes emerge from the resting condition as irregularly twisted threads. With the disappearance of the nuclear membrane metaphase beings and the chromosomes are condensed and dark-stained, in an entirely random distribution. Approaching metaphase the chromosomes condense and appear as dots or short rods which eventually unite together to form a rod-shaped mass at the metaphase plate This rod-shaped mass divides into two chromatid masses which move to either pole. In anaphase the two chromatid masses separate from each other gradually with both ends of the rods bent towards the pole. In telophase both halves reach the poles and swell to form spherical massess. Meanwhile cytokinesis is accomplished. The two spherical chromatid masses gradually fade and enter the resting stage. In some embryos large nuclei are found with different levels of polyploidy. These appear to result from repeated duplication of the chromosomes without cytokinesis.

There have been many interesting studies of aphid chromosomes. Orlando (1966) studied the embryogenesis in amphigonic and parthenogenetic *Megoura viciae* Buckton by injecting thymidine H_3 into the abdomens of the females. By radiography the incorporation of the radioactive thymidine into the nurse cells and embryos could be determined. Blackman (1974) injected radioactive thymidine into females of *Myzus persicae* Sulzer that had not produced progeny. He showed that in the initial stages the embryos appear to be supplied with nutrients by nurse cells but in later stages nutrients are supplied directly from the haemocoel of the female through the follicular epithelium. He was able to show this by autoradiographs of the chromosomes of the young embryos.

Sethi and Nagaich (1972) found that clones of *M. persicae* varied in virus transmission efficiency and also found clones with $2n = 12$ and $2n = 14$. They could not, however, correlate virus transmission efficiency with chromosome number. Blackman (1971) also found the diploid number of *M. persicae* to be $2n = 12$ and $2n = 14$.

Aphid chromosomes have been studied to obtain more information on insecticide resistance. Blackman and Takada (1976) found populations of *M. persicae* from greenhouses in Britain that had a structurally heterozygous chromosome complement. Biometric data from somatic metaphase chromospmes, and the pairing configurations of chromosomes at spermatocyte meiosis, indicate that it is either a simple or a reciprocal translocation involving autosomes 1 and 3. All except one of the clones started from these populations showed high levels of esterase activity indicative of resistance to organophosphorous insecticides. A similar or identical translocation was found in samples of *M. persicae* from Japan and California. Blackman, Takada and Kawabami (1978) have presented more information on the chromosomal rearrangements involved in the insecticide resistance of *M. persicae*.

Many scientists have studied aphid chromosomes in hope of finding answers to taxonomic problems. There have been several major papers that listed the chromosome numbers of aphids. Shinji (1931) listed 37 species, Makino (1951) 93 species, Sun and Robinson (1966) 50 species, Robinson and Chen (1969) 110 species, Kuznetsova and Shaposhnikov (1973) 270 species, and Gut (1976) 55 species.

Much of the early work on aphids is of limited value because it is difficult to know the identification of the species the workers were studying. Kuznetsova and Shaposnikov (1973) state that it would be difficult to assign some of Shinji's or Stevens' species to the correct contemporary genera or to identify them with previously described species, Fox (1956) indicated that the information on 31 of Makino's aphid species cannot be used because of the limited information on identification.

Kuznetsova and Shaposhnikov's (1973) review lists the chromosome number of 273 species of which 197 have been studied karyologically recently. The authors use the term aphids broadly to include Phylloxeridae and Adelgidae. For each aphid species the authors have given the karyological data, all the available information that may contribute to the precise identification of the species such as data, site of collection and food plants, and the literature reference for each species. They report that there are chromosome numbers of aphids from $2n = 4$ to $2n = 40$, with the exception of $2n = 36$.

Various studies have indicated that sexual female aphids have the same chromosome numbers as parthenogenetic ones but that males have one thromosome less. Female aphids are XX and males are XO. Shinji (1963) found that ***Euceraphis betulae*** Baker had more than one X chromosome in the male. Blackman (1974) studied ***E. betulae*** and also ***Euceraphis punctipennis*** (Zetterstedt) and found two pairs of X-chromosomes of different lengths in each species. The sex determination system he considered to be X_1X_2O.

Even with the large number of karyotypes of aphids studied there have been serious difficulties in attempts to determine the basic chromosome number from which the others have been derived. Shinji (1931) suggested that the diploid chromosome number $2n = 6$, which was the smallest number of those he studied, was the most primitive, and that the other numbers had all evolved from the primitive number. Shinji also stated that the number of chromosomes and specific body characters were so closely related that one could safely judge the evolutional scale of any aphid by the number of chromosomes.

Recently both ***Myzaphis rosarum*** Kaltenbach (Harper and MacDonald, 1966) and ***Gypsoaphis oestlundi*** Hottes (Sun and Robinson, 1965) have been found to have chromosome number of $2n = 4$. If Shinji's conclusion is accepted then the primitive chromosome number for aphids should be 4. Chen (1968) accepted this conclusion and believed that all other chromosome number of aphids were derived by fragmentation. Sun and Robinson (1966) suggested that $2n = 8$ was the most primitive number as this was the modal number found in their studies of over 50 species.

At present there is still disagreement as to whether high or low numbers are the most primitive. Kuznetsov (1968) thinks that chromosome numbers have undergone complicated evolutionary changes and in order to tell with any confidence which number was the original one, it will be necessary to have cytological data selected strictly from the systematic point of view.

When chromosome number only is considered there are several genera in which each species in the genus has the same number of chromosomes. Among these are:

Genus	*Diploid number*	*No. species examined*
Asiphum	10	3
Brachycaudus	12	5
Dysaphis	12	16
Eriosoma	12	3
Macrosiphoniella	12	4
Myzocallis	10	3
Pemphigus	20	6

There are also a number of genera which the species within the genus may have different chromosome numbers. Among these are :

Genus	*Didloid number*	*No. species examined*
Acyrthosiphon	8	1
	10	3
Aphis	6	1
	8	24
Anoecia	8	3
	10	1
Anuraphis	12	3
	22	2
Chaitophorus	12	1
	14	2
	18	1
	30	1
Cinera	10	9
	14	1
	22	2
Dactynotus	8	1
	10	3
	12	20
	14	1
Forda	20	1
	28	1
Kakamia	10	3
	12	1
Macrosiphum	8	1
	10	7
Pterocomma	8	7
	30-34	2

The number of species for which we have chromosome numbers is less than 10% of the total. Only in a very few genera have many species been studied—***Aphis*** (25 species), ***Dactynotus*** (25 species) and ***Dyasphis*** (16 species).

Many workers have examined the size, shape, and number of somatic chromosomes. Harper and MacDonald (1966) and Olive (1967) pointed out that aphid chromosomes lack distinct morphological features, and that comparisons of karyotypes are seldom valuable for differentiating between species within a genus. Harper and MacDonald (1968) showed that karyotype analysis is facilitated by measuring relative lengths and areas of chromosomes rather than the total lengths and areas. They showed that very large variations can occur in total complement lengths and areas of chromosomes within a species.

A fairly accurate method of studying chromosomes is by the use of ideograms (Pagliai 1966, Olive 1967, Robinson and Chen 1969). In this method photomicrographs of somatic figures are projected on a screen, chromosome lengths are measured, and the lengths paired. The mean of the lengths of the paired chromosomes is used in the ideogram. Comparative analysis of chromosome lengths reveals that karyotypes with the same diploid chromosome number are not always identical. This was demonstrated by the karyotypes $2n = 8$ (Sun and Robinson, 1966), $2n = 12$ (Kuznetosova, 1968), and $2n = 20$ (Harper and MacDonald, 1966).

Kuznetsova (1968) found in studies of *Dysaphis* that the two longest chromosomes are the pair of sex chromosomes. This was determined by the absence of one of them in males of the species. In other genera of aphids the longest chromosomes have been found to be the sex chromosomes also (Stevens 1909, Shinji 1931, Lawson 1936, Cognetti and Cognetti Varriale 1961, Pagliai 1965).

Kuznetsova (1968) found that in comparing different genera and sub-genera there was a definite correlation between relative lengths of the sex chromosomes and the systematic position of the taxa in the subtribe Anuraphidina. There was a tendency towards abbreviation of sex chromosomes in the evolution of the group. He also found that in two species of ***Anuraphis*** with a diploid number of $2n = 12$ and in two closely related species with $2n = 22$, the ratio of the sum of the autosome length to the length of the sex chromosomes was approximately the same for the four karyotypes. Sun and Robinson (1966) noted that aphid species with the lower chromosome numbers 2n = 4 or 6 were characterized by having large chromosomes, while those with higher chromosome number 2n = 18 or 20 had much smaller sized chromosomes.

Robinson and Chen (1969) used the different chromosome numbers of *Rhopalosiphum padi* Linnaeus 2n = 8, and *R. fitchii* (Sanderson) 2n = 10 to separate these two similar species in field ecological studies. Blackman, Eastop, and Hills (1977) were able to readily separate two *Amphorophora* species by chromosome numbers. The one on raspberry *A. idaei* Börner had 2n = 18 and the one on blackberry *A. rubi* (Kaltenbach) had 2n = 20.

Now that satisfactory and simple techniques are available for studying aphid chromosomes it is expected that additional information will become available on embryogenesis, insecticide resistance, and that other data will aid in clarifying the evolutionary and taxonomic status of species and higher categories of aphids.

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A CHECK-LIST OF CHROMOSOME NUMBERS IN APHIDS WITH COMMENTS

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Aphids (Aphidoidea, Sternorhyncha, Homoptera), popularly known as plant-lice are sap-sucking, minute, parthenogenetically fast reproducing common pests of a large number of fruit, vegetable, flowering, ornamental, timber and wild plants on the one hand and vector of a number of plant virus diseases on the other, have a complicated eco-dependent flexible life-cycle as compared to most other groups of insects (Behura, 1978). Thelytoky (diploid parthenogenesis) is the main mode of reproduction in this group (White, 1973). The 'holocyclic' (whole cycle) or cyclical parthenogenesis is the common form of life-cycle where diploid parthenogenetic females of spring, summer and autumn generations alternate with a single sexual winter generation while, under unfavourable environmental conditions some species have the 'anholocyclic' life cycle for secondarily losing the sexual part. The chromosome number and behaviour at every stage in the life cycle of different species of aphids have seldom been studied as that of the cyclical parthenogenetic elm-aphid, *Tetraneura ulmi* (Schwartz 1932; White 1973). The over-wintering diapaused eggs of this species with 2n = 14 chromosomes (3 long and four short pairs) develop into females inside the leaf-gall. Each female (2n = 14) gives rise partheonogenetically to about 40 wingless diploid female offspring—'fundatrices' which in their turn give rise parthenogenetically to the next generation of winged 'emigrants'. Then they come out of the gall and migrate at the advent of the spring to warmer - regions and infest various species of grass as the secondary host. There they multiply parthenogenetically for several generations of 'exules', the last of which gives rise parthenogenetically to winged 'sexuparae' and that by modified maturation division process form 'sexules' after returning to the host plant, the elm tree. The males are formed by the elimination of one X chromosome as a laggard of the bivalent which remains in the middle of the anaphase spindle during the first maturation divison. The males thus formed have 2n = 13

* Grateful acknowledgement is made to the U. G. C. for the National Fellowship.

chromosomes (12 + X) consisting of 5 long and 8 short ones while the females retain the original constitution of 14 chromosomes (12 + XX) received on fertilization at the beginning of their life cycle. The meiosis in males is anomalous and of modified type because the single X at anaphase I remains in stretched out condition between the long axis of two poles as a bipartite body but eventually moves to one pole which gets more cytoplasm. The secondary spermatocyte without the X and very little cytoplasm degenerates while the X bearing sperms (6A + X) with more amount of cytoplasm are functional; as a result, on fertilization only females are produced (12 + XX) to follow the life cycle mentioned above. The XO males are therefore, only homogametic since they can produce only the X bearing sperms. The maturation of parthenogenetically developing eggs of aphids has been worked out in detail by Cognetti (1961). In species of *Phylloxera* two kinds of sexuparae have been detected. However the genetic systems of aphids are of varied nature, the precise knowledge of which is very much lacking. White (1973) suspects that the complicated lacanoid, comstokilla and diaspidid systems in coccids have been derived from 'aphid' type.

The complicated lifecycle, the common occurrence of polymorphism and eco-geographical factors have made the taxonomy of aphids a difficult field. However, chromosomal studies of aphids have been deployed as an additional tool in taxonomy from early part of the century (Stevens, 1906; Morgan, 1909; Shinji 1931) which is being continued upto the present time (Kuznetzova, 1968; Robinson and Chen, 1969, Gut, 1976; Blackman, Eastop and Hills, 1977). We have so for information of chromosome numbers and structures of about 418 species of which some 20 were unidentified (Makino, 1956) against about 4,000 species described by the taxonomists (Table 1).

The handling of aphid chromosomes underwent two phasic changes. It began with the use of classical technique of section cutting of fixed materials of both sexes, specially males (Morgan, 1909; Stevens, 1906; Shinji, 1931) which ensured limited progress and the results were less dependable. This was replaced by the squashing of ovaries and embryos removed from apterous females originally initiated by Colling (1955) and followed by others (Dionne and Spicer, 1965; Sun and Robinson, 1966; Olive, 1967; Gut, 1976). Since the contribution of Indian cytologists on chromosomes of aphids is rather limited (Table 1) in spite of the fact that India is rich in aphid fauna, the present check-list has been prepared with a view to encourage the study as the field has immense cytogenetical importance. In preparing the list (Table 1) the present author has consulted reviews and papers within his limited resources and to economize space of printing, the name of the original worker has not been cited. Further, the diploid number in many species has been interpreted by the author from the available data, so also the sex determining mechanism and those have been marked with asterisk (*). The check-list prepared by Makino (1956) contained many pitfalls as pointed out by Fox (1956) who mentioned 31 species against 93 listed by Makino. In spite of this limitation the author has followed Makino's list as the settlement of the disputed points can be resolved only when substantial data and information about different species would be available. The chromosome number of some 20 unidentified species referred from their host plants has been listed by Makino (1956). The same has been retained by the present author as the species may be identified in due course.

The chromosomes of aphids are characteristically holocentric showing no demarkable longitudinal differentiation and that limits to some extent the intra and interspecific evaluation of their relationship. However, Gut (1976) claimed that one or two chromosomes having constrictions might detach in some nuclei giving rise to in the same preparation nuclei with variable numbers as $2n = 6$, 7 or 10, 12 etc. Khuda-Bukhsh and Datta (1978) also suggested the fragmentation of A_1 in $2n = 8$ to give rise to $2n = 10$ chromosomes in some nuclei of *Lipaphis erysimi*. How ever determination of the exact diploid number sometimes poses a problem due to factors like the fragility of chromosomes at the constricted part as mentioned above, the difficulty to identify the male embryos, seasonal variations in count, structural heterozygosities, etc. (Gut, 1976). Thus *Myzus persicae* was reported to have different diploid chromosome number and structure as $2n = 14$ due to the breaks in A_2 and A_3 (Blackman, 1971), $2n = 13$ due to dissociation of only A_3, structural heterozygosities involving autosomes No. 1 and 3 (Blackman and Takada, 1977) and so on (Table 1). The diploid number in male is generally one less than that of the female because normally in XO : XX mechanism, the male embryo contains one X chromosome less ($2n - 1$). The frequency of species with multiple Xs appeared not very low, 17 out of the 398 (4.2%) in the present list even though in many spceies the sex chromosome mechanism remains unknown. Anyhow in. species with multiple sex-chromosome mechanism, the males have one set of X chromosome less than that of females as in *Phylloxera caryaecaulis*, *P. fallax*, *Stomaphis janois* etc., males have 2Xs and females 4Xs; in *Drepanosiphum planianodes* and *Neocalphis* etc. males have 3Xs and female 6Xs; in *Nectrarosiphum* *ribicola*, *Euceraphis betulae* and *Pterochlorus tropicalis* etc. males have 4Xs and females 8Xs. Species having more than 4Xs in males have not been reported so far (Table 1). The difference in the diploid number in male and female of species having multiple sex chromosome would depend on the number of multiple Xs. The multiple Xs in males in different species behave uniformly during spermatogenesis exactly like a single X. A set of Xs undergoes reduction as a mass in first maturation division of eggs destined to form males (White, 1973). The Y chromosome is absent in males as a rule and an instance of X-autosome translocation to give rise to to the neo-X and the neo-Y mechanism has not been encountered so far. These facts led White (1973) to advocate that the neo-XY individual would not survive and the X chromosome could be in a state of evolutionary isolation.

It appeared that the taxonomy of aphids is not stabilized at the species as well as the supergeneric levels. The cytological data sometimes gave good indication. The diploid numbers in species included in the same tribe varied widely. Gut (1976) pointed out that it ranged between 4 and 40 in Aphidini, between 6 and 30 in Chaitophorini, between 8 and 38 or 40 in Phyllaphidini. However, congeneric species differing widely in chromosome numbers has been recorded in many genera like *Acrythosiphon*, *Amphorophora*, *Chaitophorus*, *Macrosiphum*, *Phylloxera* etc. (Table 1). On the other hand the chromosome number in good many species of a genera showed a stability and characteristic number as found in the genera *Aphis*, *Cinara*, *Dactynotus*, *Dysaphis*, *Kakima*, *Macrosiphoniella*, *Rhopalosiphum* etc. (Table 1). Since a large number of species within a genus and between genera possess the same diploid number, Harper and MacDonald (1966) introduced the system of measuring the relative length rather than the actual length to make meaningful comparison of the karyotopes of similar form. In view of this Robinson and Chen (1969) made analysis of idiograms of some 110 species of aphids and reported that there were at least five common karyotypes as (i) 2n = 8, 6 long and about same size and 2 formed a slightly short pair eg., *Aphis* sp; (ii) 2n = 8, 6 long of same size and 1 pair very short eg., *Pterocomma* sp.; (iii) 2n = 10, 4 long, 2 medium and 4 short as in *Macrosiphum* sp., (iv) 2n = 10, 1 pair long and 4 pairs medium to short as in *Cinara* sp.; (v) 2n = 12, 2 long, 6 medium and 4 short as in *Dactynotus* etc. Similar karyotypic analysis based on relative percentage length has been followed by other workers as this offered some clue when other avenues of comparison were not rewarding.

There are various claims as to the modal number of chromosomes in aphids as 2n = 6 by Shinji (1931), 2n = 8 by Sun and Robinson (1966), 2n = 4 by Chen (1968) and so on. These authors favoured some lower diploid number from which fragmentation mainly led to the evolution of higher number. They did not cite any fossil evidence in support of their view. An analysis of the present data (Table 1) represented in the histogram (Fig. 1) would show that the diploid number of 4 in 2 genera,

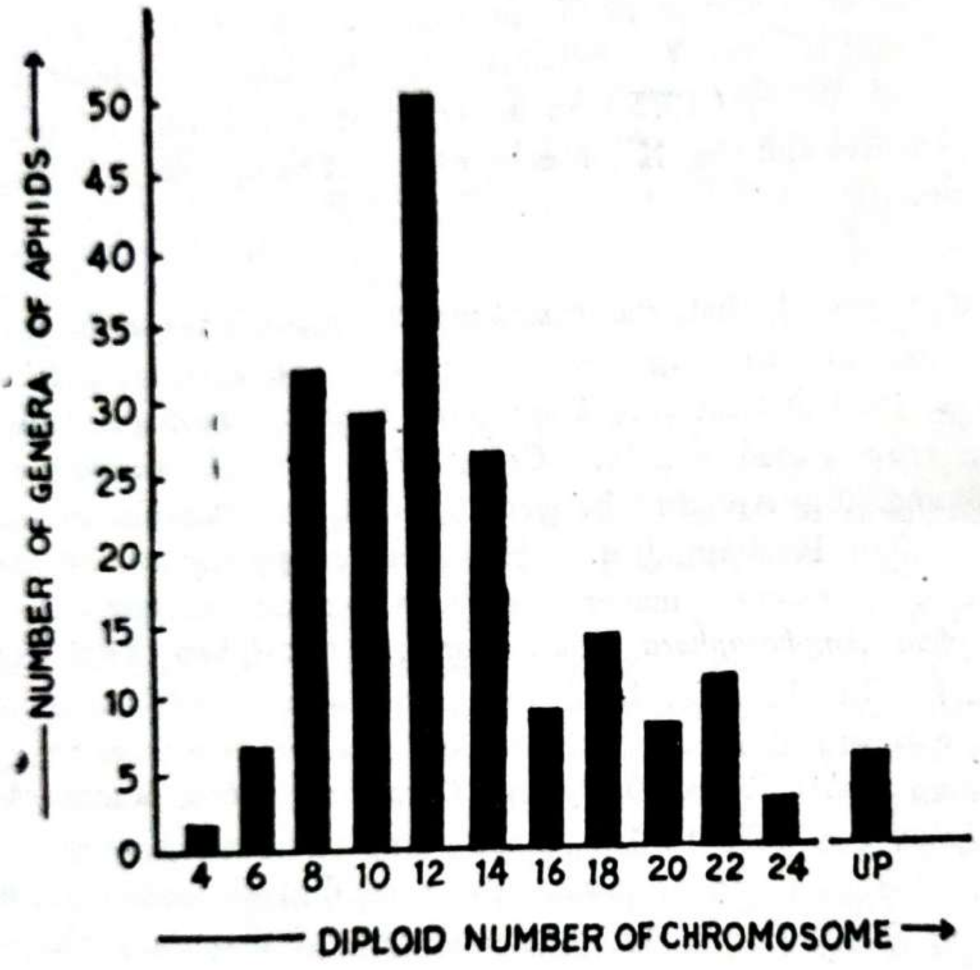

Fig. 1

6 in 7 genera, 8 in 32 genera, 10 in 29 genera, 12 in 50 genera, 14 in 26 genera, 16 in 9 genera, 18 in 14 genera, 20 in 8 genera, 22 in 11 genera, 24 in 3 genera and upward numbers in 6 genera. The diploid numbers in different species ranged between 4 and 73 (Table 1). Out of 418 species listed including 20 unidentified ones from Makino's list, 3 species had diploid number of 4 chromosomes, 12 had 6, 75 with 8, 57 with 10, 135 with 12, 43 with 14, 13 with 16, 27 with 18, 22 with 20, 17 with 22, 3 with 24 and 19 variable upward diploid numbers (Fig. 2). As the frequency-distribution peak of diploid numbers appeared at 12 within the crowded range between 8 and 22 chromosomes (Fig 2), it

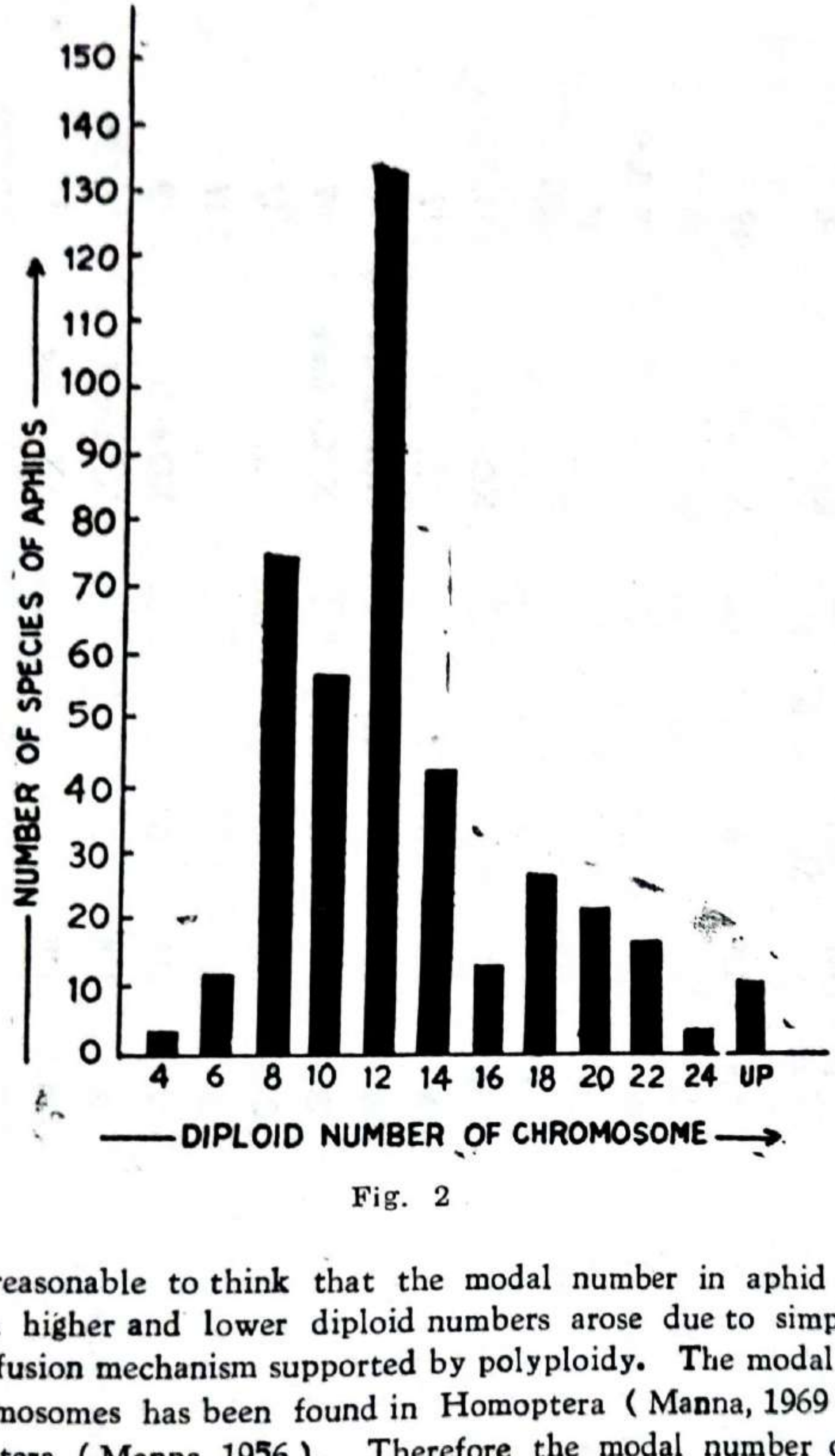

Fig. 2

would be reasonable to think that the modal number in aphid was 12 from which higher and lower diploid numbers arose due to simple fragmentation-fusion mechanism supported by polyploidy. The modal number of 12 chromosomes has been found in Homoptera (Manna, 1969) and 14 in Heteroptera (Manna, 1956). Therefore the modal number of 12 for aphids is more suggestive.

Most of the aphidian cytologists carry the view that simple fragmentation and fusion played the major role in the evolution of karyotypes of different species which has been supported by the experimental result of Ris (1942). However the important role of polypolidy

TABLE 1

Chromosome number in different species of aphids. (*) Number inferred.

Name of the species	Diploid No.		Spermatoc		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Acandus itadori	12*	11*	6	...	...	XO male	19
Acaudinum dolichosiphon	10	...	...	...	...	...	16,17
Acyrthosiphon caraganae	10	...	...	...	...	...	17,25,29
A. aff. *ignotum*	10	...	...	...	...	...	17
A. dirhodum	18	...	...	...	...	...	29
A. pisum	8	7	...	...	...	XO male	13,17,25,29
Adelges geniculatus	20	...	...	...	...	...	17
A. laricis	22	18	...	...	...	$X_1X_2X_3X_4O$ male	17
	20	18	...	...	...	X_1X_2O male	17
	21	...	...	...	...	...	17
A. tardus	20	...	...	...	...	...	17
Akkai polygoni	12*	11*	6	...	...	XO male	19
Amphorophora agathonica	14	13*	...	...	...	XX female	5,17,25
A. idaei	18	17*	...	...	...	XX female	5
A. laingi	12	...	...	...	...	...	17,25,29
A. magnoliae	12*	11*	6	...	...	XO male	19
A. (*Nectarosiphum*) *ribicola*	12*	11*	6	...	...	XO male	19
A. ribiella	12	...	...	...	...	...	29

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
A. rubi	20	19*	...	...	...	XX female	5
	21	...	...	...	...	XX female	5
Anoecia graminis	8	...	...	...	...	...	17,25,29
A. aff. *haupti*	8	...	...	...	...	...	17
A. quarci	10	...	...	...	...	...	17,25
Annuraphis catonii	22,26	...	...	...	...	...	16,17
A. farfarae farfarae	12	...	...	...	...	...	17
A. farfarae	12	...	...	...	...	...	16
A. farfare dianae	12	...	...	...	...	...	16,17
A. pyrilaseri	12	...	...	...	...	...	16,17
A. subterranea	22,26	...	...	...	...	...	16,17
Aphanostigma piri	8	...	...	...	...	...	17
Aphrastasia pectinatae	20	18	...	...	...	X_1X_2O male	17
Aphid	14*	13	...	...	...	XX female	19
	26 (4n)	...	...	...	13	...	19
Aphid (Beech, wooly)	16*	15	8	7,8	...	XO male	19
Aphid (Birch, paper)	...	17*	9	...	...	...	19
Aphid (Clover)	...	15*	8	...	...	...	19
Aphid (Goldenrod, beach)	12	11*	6	5,6	...	XO male	19

Table 1—(*Contd.*)

Name of the species	Diploid No. female	Diploid No. male	Spermatoc. M. I	Spermatoc. M. II	Oocy. M. I	Remarks	Ref. No.
Aphid (Goumig)	10	...	...	...	5	...	19
Aphid (Maple)	32*	31*	16	15,16	...	XO male	19
Aphid (Milkwood, black)	8	7*	4	3,4	...	XO male	19
Aphid (Milkwood, orange)	8	...	...	...	7,8	..	19
Aphid (Milkwood, pale)	14*	13*	7	7	...	...	19
Aphid (Nasturtrium)	8*	7*	4	3,4	...	XO male*	19
Aphid (Oak red I)	14*	13*	7	7	...	...	19
Aphid (Oak red II)	16*	15*	8	...	...	...	19
Aphid (Oak white)	14*	13*	7	...	...	...	19
Aphid (Oenothera II)	8*	7*	4	4	...	...	19
Aphid (Pea)	8	7*	...	...	8	...	19
Aphid (Rose green)	14	13*	7	6,7	14	XO male*	19
Aphid (Rose, migratory)	18	...	...	...	9	...	19
Aphid (Star cucumber)	10*	9*	5	4,5	...	XO male	19
Aphid (Willow, Saranac)	10*	9*	5	4,5	...	XO male	19
Aphis sp No. 1	8	...	...	...	...	...	25
Aphis sp No. 2	8	...	...	...	...	...	25
Aphis armata	8	...	...	...	...	...	*11*
Aphis asclepiadis	8	...	...	...	...	...	*17,25*

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	temale	male	M. I	M. II	M. I		
Aphis corniella	8	...	...	...	...	...	17,25,29
Aphis craccivora	8	...	...	...	...	...	1
Aphis epilobii	8	...	...	...	...	...	11
Aphis fabae	8	...	...	...	...	...	17
A. farinosa	6	...	...	...	...	...	17
A. genistae	8	...	...	...	...	...	11
A. gossypii	8	...	...	...	...	...	1,14,17,25
A. helianthi	8	...	...	...	...	...	17,25,29
A. heraclella	8	...	...	...	...	...	15,25,17
A. knowltoni	8	...	...	...	...	...	17,25,29
A. maculata	8	...	...	...	...	...	17,25
A. nasturtii	8	...	...	...	...	...	17,25,29
A. neogillettei	8	...	...	...	...	...	17,25,29
A. neomexicana	8	...	...	...	...	...	17,25
A. nerii	8	...	...	...	...	...	1,14
A. oenotherae	10	9	5	4,5	5	XO male	19
	...	...	9	...	...	...	19
A. pomi	8	...	...	...	...	...	17,25
A. rhamnifila	8	...	...	...	...	...	Abs. 83

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
A. rosae	8+6	...	...	...	14	...	19
	10*	...	...	...	10	...	19
A. rosae (brown)	10	10	5	5	5	...	19
	...	...	...	...	10	...	19
	10	...	...	...	10	...	19
A. rubicola	8	...	...	...	...	...	17,25,29
A. ruborum longisetosus	8	...	...	...	...	...	Abs. 83
A. rumicis	8	...	...	...	...	...	17
A. saliceti	6	5	3	2,3	...	XO male*	19
	6	...	...	...	6	...	19
A. saliceti (Harpswell willow)	6	5	3	2,3	...	XO male	19
A. sambuci	8	...	...	...	...	...	11
	14*	13*	6	...	...	XO male	19
A. sambuci horii	8	...	...	...	...	10 A + XO	17
A. spiraecola	8	...	...	...	...	...	17,25,29
A. spiraephila	8	...	...	...	...	...	17,25
A. thaspii	8	...	..	...	...	...	17,25,29,
A. varians	8	...	...	...	...	...	17
Aphis viburni	8	...	...	...	...	...	17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Aphthragelia symphoricarpi	14	...	...	...	...	...	17,25,29
Appelia schwartzi	12	...	...	...	...	...	11
Asiphum rosettei	10	...	...	...	...	...	17,25
A. sacculi	10	...	...	...	...	...	12,17,18
A. tremulae	10	...	...	...	...	...	17
Aspidaphis adjuvans	12	...	...	...	...	...	17,25,29
Atarsos grindeliae	12	...	...	...	...	...	17,25
Aulacorthum ibotum	14	13*	...	...	...	XO male	17
A. magnoliae	12	11*	...	...	...	XO male	17
A. solani	10	...	...	...	...	...	17
Bilabera fusca	...	73	37	36,37	...	XO male	19
Brachycaudus (*Thuleaphis*) *amygdalinus*	12	...	...	...	...	...	16,17
B. (*Prunaphis*) *cardui*	12	...	...	...	...	...	16,17
B. (*S. str.*) *helichrysi*	12	...	...	...	...	...	16,17
B. jacobi	12	...	...	...	...	...	11
B. (*Acaudus*) *lychnidis*	12	...	...	...	...	...	16,17
B. (*Appelia*) *prunicola*	12	...	...	...	...	...	16,17
B. spiraeae	12	...	...	...	...	...	11

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	temale	male	M. I	M. II	M. I		
Brachycolus atriplicis	14	...	...	...	...	...	29
B. cerastii	14	...	...	...	...	...	11
Brachyunguis calotropicus	8	...	...	...	...	...	15
Brevicoryne brassicae	16	15*	...	...	...	...	17,18,25,29
Calaphis sp.	18	...	...	...	...	...	17
C. *betulaecolens*	18*	17*	9	...	...	XO male	19
	20	...	...	...	...	...	17,25,29
C. *betulicola*	18	...	...	...	...	...	11
C. *flava*	18	...	...	...	...	...	11
C. *magnolicolens*	20*	19*	10	...	...	XO male	19
Callipterns luricola (nippocollis)	14*	13*	7	...	...	XO male	19
Capitophorus elaeagni	16	...	...	...	...	...	17,25
C. *hippophaes*	10	...	...	...	...	...	17,25,29
Carolinaia tade	10	9*	5	4,5	...	XO male	17,19
Cavariella sp.	10	...	...	...	...	...	17,25
C. (*Hydronaphis*) *cerauthi*	8*	7*	4	...	...	XO male	19
C. *oenanthi*	8	...	...	...	...	...	17
C. *pastincae*	8	...	...	...	...	...	11
Ceraraphis eriophori	8	...	...	...	...	...	16,17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Chaitophorus matsumurai	14	13*	...	...	...	XO male	17
C. aff. niger	30	...	...	...	...	...	17
C. populifolii	12	...	...	...	...	...	25
C. populifolii neglectus	12	...	...	...	...	...	17,25
C. populifolii populifolii	12	...	...	...	...	...	17
C. saliapterus	14	13*	7	...	...	XO male	17,19
C. saliniger	14*	13*	7	...	...	XO male	19
C. viminalis	18	...	10	...	...	...	17,19,25
Chermes pectinata	20	19*	10	10	10	...	19
C. strobilobius	22	18-19	10-11	...	...	...	19
Cholodkowskya viridana	24	...	...	...	...	...	17
Chomaphis (S str.) *mira*	8	...	...	...	...	...	17
C. (*Toxopterina*) *vandergooti*	8	...	...	...	...	...	17
Chromaphis magnoliae	8*	7*	4	...	...	XO male	19
Cinara boerneri	10	...	...	...	...	...	17
C. braggii	10	...	...	...	...	...	17,25,29
C. coloradensis	10	...	...	...	...	...	17,25
C. fornacula	10	...	...	...	...	...	17,25
C. hyperophila	10	...	...	...	...	...	17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
C. laricicola	10	...	...	...	...	...	17
Cinara laricifex	10	...	...	...	...	...	17,25
C. nuda	10	...	...	...	...	...	17
C. pilicornis	14	...	...	...	...	...	17
C. pinea	10	...	...	...	...	...	25
	14	...	...	...	...	...	17
C. pini	10	...	...	...	...	...	17
C. pinidensiflorae	22	21*	...	...	...	XO male	17
Coloradoa artemisiae	16	...	...	...	...	...	25
Cryptaphis bromi	16	...	...	...	...	...	17,25
C. poae	16	...	...	...	...	...	29
Cryptomyzus ribis	12	...	...	...	...	...	17,25,29
Dactynotus ambrosiae	12	...	...	...	...	...	17,25
D. anomales	12	...	...	...	...	...	17
D. basalis	8	...	...	...	...	...	17
D. bradburgyi	12	...	...	...	...	...	17
D. chrysopsidicola	12	...	...	...	...	...	17
D. cirsii	10	...	...	...	...	...	17,25,29
D. (Uromelon) compositae	12	...	...	...	...	...	*Abs. 82*

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
D. gobonis	14	13*	...	...	...	XO male	17
D. gravicornis	12	...	...	...	...	...	17
D. helianthicola	12	...	...	...	...	...	17
D. nigrotuberculatus	12	...	...	...	...	...	17
D. paucosensoriatus	12	...	...	...	...	...	17,25,29
D. pseudoambrosiae	12	...	...	...	...	...	17
D. reynoldensis	12	...	...	...	...	...	17
D. richardsi	12	...	...	...	...	...	17,25
D. rudbeckiae	12	...	...	...	...	...	17
D. ruralis	10	...	...	...	...	...	17
D. russelae	12	...	...	...	...	...	17
D. sonchellus	12	...	...	...	...	...	17
D. sonchi	12	11*	...	...	...	XO male	17
D. taraxaci	12	...	...	...	...	...	17,25
D. tissoti	12	...	...	...	...	...	17
D. tuataiae	12	...	...	...	...	...	17
D. verbesinae	10	...	...	...	...	...	17
Dactynotus sp No. 1	12	...	...	...	...	...	17,25
Dactynotus sp No. 2	12	...	...	...	...	...	25

Table 1—(Contd.)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Dactynotus sp No. 3	12	...	...	...	...	...	25
Dactynotus sp No. 4	12	...	...	...	...	...	25
Dactynotus sp No. 5	12	...	...	...	...	...	25
Dilochnus laricis	10*	9*	5	4,5	...	XO male	19
D. pinidensiflorae	22*	21*	11	10,11	...	XO male	19
Diuraphis (Holcaphis) holci	14	...	...	...	...	...	11
Drepanaphis acerifolii	38*	35*	19	...	...	$X_1X_2X_3O$ male	19
	38	37*	...	...	...	XO male	17
Drepanosiphum plaianoides	30*	27*	15	8	...	$X_1X_2X_3O$ male	19
	30	29*	...	...	...	XO male	17
D. (H.) frequens	14	...	...	...	...	...	11
Dreofusia normannianae	22	...	...	...	...	...	17
Dysaphis (S. str.) *affinis*	12	...	...	...	...	...	16,17
D. (Umbelliferaria) aizenbergi	12	...	...	...	...	...	16,17
D. (S. str.) *anthrisci anthrisci*	12	11*	...	...	...	XO male	16,17
D. (S. str.) *chaerophyllina*	12	...	...	...	...	...	16
D. (S. str.) *anthrisci majkopica*	12	...	...	...	...	...	16,17
D. (S str.) *chaeporhillina*	12	11*	...	...	...	XO male	17
D. (*Anuromyzus*) cotoneasteris	12	...	...	...	...	...	16,17

Table 1—(Cantd.)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
D. (Crataegaria) crataegi	12	...	...	...	...	...	16,17
D. (U.) hirsutissima	12	...	...	...	...	...	16,17
D. (S. str.) *malidauci*	12	...	...	...	...	...	17
D. (Cotoneasteria) microsiphon	12	...	...	...	...	...	16,17
D. (S. str.) *radicola radicola*	12	...	...	...	...	...	16,17
D. (Pomaphis) mali	12	...	...	...	...	...	16,17
D. (P.) pyri	12	...	...	...	...	...	16,17
D. (P.) reaumuri	12	...	...	...	...	...	16,17
D. (P.) sorbi	12	...	...	...	...	...	16,17
Dysaphis (Crataegaria) sp.	12	...	...	...	...	...	16,17
Eopineus pineoides	22	...	...	...	...	...	17
E. strobi	22	...	...	...	...	...	17
Eriosoma crataegi	12	...	...	...	...	...	17,25
E. lanigerum	12	...	...	...	...	...	12,17,25,29
E. ulmi	12	...	...	...	...	...	17
Eucallipterus tiliae	38,40 ?	...	...	...	...	...	17
Euceraphis betulae	8	8	8	6	8	$X_1X_2X_3X_4O$ male	19
	12*	...	...	...	...	$X_{1-8}+4A$ female*	17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
E. betulae	10	8	...	...	...	4A+2B+4X female	3
						4A+2B+2X male	3
E. deducta	8	...	...	...	...	...	17,25
E. punctipennis	8	...	...	...	...	...	29
	8	6*	...	...	...	2A+2B+2X male	3
						2A+2B+4X female	3
E. punctipennis	12	8	...	...	...	4A+4X male*	17
						4A+8X female*	17
Eulachnus piniformosanus	14*	13*	7	...	...	XO male	19
Forda formicaria	20	...	...	...	...	...	17,25
F. marginata	28	...	...	...	...	...	17,25
Gillettella cooleyi	22	20	...	...	...	18A+X_1X_2O male	17
G. coweni	22	...	...	...	...	...	17
Glyphina betulae	10	...	...	...	...	...	17
G. schrankiana	10	...	...	...	...	...	17
Gypsoaphis oestlundi	4	...	...	...	...	...	17,25,29
Hayhurstia atriplicis	14	...	...	...	...	...	17,25
Hyalopterus pruni	10	...	...	...	...	...	17,25
	10	9	5	...	...	XO male	19

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Hyadaphis foeniculi	14	...	...	...	...	...	11
H. passerinii	12	...	...	...	...	...	17
Hyperomyzus lactucae	12	...	...	...	...	...	17,25
Hysteroneura setariae	12	...	...	...	...	...	17,25
Impatientinum asiaticum	16	...	...	...	...	...	11
Kakimia cynosbati	10	...	...	...	...	...	25
K. essigi	10	...	...	...	...	...	25,29
Kakimia ribiella	12	...	...	...	...	...	25
K. thomasi	10	...	...	...	...	...	25,29
Lachnus tropicalis	16	...	...	...	...	...	15,17
Lipaphis erysimi	10	...	...	...	...	...	11
L. erysimi	8	...	...	...	...	Frag. A_1 makes 10	14
Loboptera decipiens	34*	33	17	16,17	...	XO male	19
Longicaudus trirhodus	12	...	...	...	...	...	11
Longiunguis oonacis	8	...	...	...	...	...	17
Longiunguis pyrarius	8	...	...	...	...	...	17
Macrosiphoniella absinthii	12	...	...	...	...	...	15,25,29
M. artemisiae	12	...	...	...	...	...	11
M. ludovicianae	12	...	...	...	...	...	17,25

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
M. illefolii	12	...	...	...	...	...	11
M. oblonga	12	...	...	...	...	...	11
M. persequens	12	...	...	...	...	...	11
M. sanborni	12	...	...	...	...	...	14,17
M. tanacetaria	12	...	...	...	...	...	17,25,29
M. trimaculata	12	...	...	...	...	...	11
Macrosiphum avenae	18	...	...	...	...	...	25,29
M. cornifiliae	14*	13*	7	...	...	XO male	19
M. euphorbiae	10	...	...	...	...	...	25,29
M. gei	10	...	...	...	...	...	11
M. geranii	10	...	...	...	...	...	17,25
M. gobonis	14*	13*	7	...	...	XO male	19
M. hamiltoni	10	...	...	...	...	...	17,25
M. hellebori	10	...	...	...	...	...	11
M. ibetum	14*	13*	7	...	...	XO male	19
M. kickapoo	10	...	...	...	...	...	17,25
M. manitobensis	10	...	...	...	...	...	17,25,29
M. pallidum	10	...	...	...	...	...	17,25
M. pisi	8	7	4	4	8	XO male	19

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
M. rosae	10	...	...	...	...	...	17
M. (Sitobion) rosaeformis	18	...	...	...	...	...	Abs. 82
Macrosiphum saloanifolii	10	9	5	4,5	10	XO male	19
M. sonchi	12*	11*	6	...	...	XO male	19
Macrosiphum sp.	10	...	...	...	...	...	17,25
Maculolachnus sijpkensi	10	...	...	...	...	...	17,25
Masonaphis lambersi	10	...	...	...	...	...	11
M. rubicola	12	...	...	...	...	...	25
M. wahnaga	10	...	...	...	...	...	17,25,29
Megoura lespedezae	12	11*	...	...	...	XO male	17
M. viciae	10	9*	...	...	...	XO male	17
Melanaphis bambusae	10	9*	...	...	...	XO male	17
Melanoxantherium solijaponica	8*	7*	4	...	...	XO male	19
Melanoxanthus salicicola	...	6	6	...	...	...	19
M. salicis	6	6*	...	3	6	...	19
Metopolophium dirhodum	18	...	...	...	...	...	17,25
Microlophum carnosum	18	...	...	...	...	...	17,25
M. evansi	16	...	...	...	...	...	17
Micerotarsus pteridifoliae	12*	11*	6	5,6	...	XO male	19

Table 1—(Contd.)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Mindarus abietinus	12	...	...	...	...	...	17,25
M. obliqueus	12	...	...	...	...	...	17,25
Moritziella caryaefolii	8	...	...	...	...	...	17
Mordvilkoja vagabunda	20	...	...	...	...	...	12,17,25
Myzaphis rosarum	4	...	...	...	...	...	13,17,18
Myzocallis castanae	14*	13*	7	...	...	XO male	19
Myzocallis castanicola	14	...	...	...	...	...	17
M. coryli	14	...	...	...	...	...	11
M. discolor	14	...	...	...	...	...	17,25
M. kuricola	12	12	7	7	...	...	19
M. myricae	14	...	...	...	...	...	11
M. punctata	14	...	...	...	...	...	17,25,29
Myzocallis querei	18*	17*	9	...	...	XO male	19
M. ulmifolii	8	...	...	...	...	...	18
Myzodes persicae	12*	11*	6	5,6	...	XO male	17,19
	12	...	...	...	...	...	17
	14	...	...	...	...	...	17
	12,13,14	...	...	...	...	Frag in A_2,A_3	2,17
M. physocarpi	20	...	...	...	...	...	17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Myzus (*Nectarosiphon*) *ajugae*	12	...	...	...	...	...	11
M. (*N.*) *ascalonicus*	12	...	...	...	...	...	11
M. (S. str.) *cerasi*	10	...	...	...	...	...	17,25,29
M (*N.*) *certus*	12	...	...	...	...	...	11
M. (*Nevskia*) *lithri*	12	...	...	...	...	...	17
M. linderae	12	11	6	5,6	...	XO male	19
M. (*Netarosiphon*) *myosotidis*	12	...	...	...	...	...	11
M. persicae	12*	11*	6	5,6	...	XO male	19
M. persicae	12,13,14	...	...	...	...	Frag. A_2, A_3	2,17
	12	...	...	...	...	...	25,29
	12,13	...	...	...	...	Trans A_1&A_3, Frag. A_3	4
M. (*N.*) *persicae*	10,11,12	...	...	...	...	anholocyclic life-cycle	Abs. 84
M. physocarpi	20	...	...	...	...	...	25,17
M. sansho	12*	11*	6	5,6	...	XO male	19
M. sugrui	12*	11*	6	5,6	...	XO male	19
M. ribis	16*	14*	8	5	...	X_1X_2O male	19
Nasonovia lactucae	12	...	...	...	...	...	29
Neanuraphis itadori	12	...	...	...	...	...	17
Nectarosiphum ribicola	12	8	8	6	...	$X_1X_2X_3X_4O$ male	19

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
Neo-Calphis	12*	9*	...	...	...	$6A+X_1X_2X_3O$ male	19
Neocalaphis manoliae	8	7*	...	...	...	6A+XO male	17
N. magnolicolens	20	19*	...	...	...	18A+XO male	17
Neoceruraphis viburnicola	14	...	...	...	...	...	16,17,25,29
Neoprociphilus aceris	14	...	...	...	...	...	17,25
Neotherioaphis chhenafuli	6	...	...	...	...	...	1
Nippocallis kuricola	14	13*	...	...	...	12A+XO	17
Ovatomyzus boraginacearum	12	...	...	...	...	...	11
Ovatus insitus	12	...	...	...	...	...	17
? *Oestlundia rubicola*	12	11*	...	...	...	10A+XO male	17
Paraschizaphis scirpi	8	...	...	...	...	...	11
Pemphigus bursarius	20	...	...	...	...	...	17
P. filafinis	22	...	...	...	...	...	11
P. fuscicornis	20	...	...	...	...	19A+XO male	17
P. junctisensoriatus	20	...	...	...	...	...	17,25
P. passeki	22	...	...	...	...	...	11
P. populicaulis	20	...	...	...	...	...	17,18
P. populitransversus	20	...	...	...	...	...	12,17
P. pyriformis	20	...	...	...	...	...	19

Table 1—(*Contd.*)

Name of the species	Diploid No. female	Diploid No. male	Spermatoc. M. I	Spermatoc. M. II	Oocy. M. I	Remarks	Ref. No.
P. spirothecae	20	...	...	...	...	...	17
Periphyllus acericola	18	...	...	...	...	...	11
P. aceris	18	...	...	...	...	...	11
	...	19*	10	...	...	...	19
P. coracinus	18	...	...	...	...	...	11
P. hirticornis	18	...	...	...	...	...	11
P. koelreuteriae	20*	19*	10	...	...	...	17,19
P. lyropictus	18	...	...	...	...	...	11
P. negundinis	20	...	...	...	...	...	17,25,29
P. testudinaceus	18	...	...	...	...	...	11
Periphyllus sp.	20	19	...	...	...	18A + XO male	17
Phorodon humuli	12	11	6	6	...	XO male, X = V	19
P. pruni	12	...	...	...	...	...	17
Phyllaphis coweni	6	5	3	3,2	...	XO male	19
P. fagi	26*	25*	13	...	...	XO male	17,19
Phyllodromia germania	24	23	12	11,12	...	XO male, X-A Trans in male	19
Phloeomyzus passerinii	10	...	...	...	...	...	11
Phylloxera caryaecaulis	6 (8)	5 (6)	2 (4)	2 (4)	6	X_1X_2O male	19
P. caryaefoliae	8	...	...	...	...	migrant	19

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
P. caryaeglobuli	22	22	...	...	...	...	19
P. depressa	6	...	...	...	...	Stem mother	19
Phylloxera fallax	12*	10	6	4,6	12	X_1X_2O male	19
P. globosum	6	6	...	...	...	...	19
P. quercus	12	11*	...	...	...	10A+XO male	17
P. subelliptica	6	...	...	...	...	Migrant	19
Pineodes pinifoliae	22	...	...	...	...	...	17
Pineus pini	22	...	...	...	...	...	17
P. similis	22	...	...	...	...	...	17
Plocamaphis flocculosa	30-34	...	...	...	...	...	17
Prociphilus fraxinifolii	20	...	...	...	...	...	17,25
Protolachnus thumbergii	14	13	...	...	...	12A+XO male	17
Pseudocercidis rosae	12	...	...	...	...	...	17,25
Pterochlorus tropicalis	16*	12*	8	8	...	$X_1X_2X_3X_4O$ male	19
Pterocomma bicolor	8	...	...	...	...	...	17,25
P. jacksoni	30-34	...	...	...	...	...	17
P. pilosum	8	...	...	...	...	...	17
P. populeum	8	...	...	...	...	...	17
P. salicis	30-34	...	...	...	...	...	17

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
P. salijaponicum	8	7	...	...	...	6A+XO male	17
P. smithiae	8	...	...	...	...	...	17,25,29
P. steinheili	8	...	...	...	...	...	17
P. tremulae	8	...	...	...	...	...	17
Rhopalomyzus lonicerae	12	...	...	...	...	...	17,25
Rhopalosiphoninus latysiphon	6+1	...	...	...	...	...	11
Rhopalosiphum cerasifoliae	8	...	...	...	...	...	17,25
R. fitchii	10	...	...	...	...	...	29,17,25
R. incertum	10	...	...	...	...	...	17
R. maidis	8	...	...	...	...	...	1,17,25,29
R. nymphaeae	8,16	...	...	...	...	...	1,17,25,29
R. padi	8	...	...	...	...	...	17,25
R. rufiabdominalis	8	...	...	...	...	...	11
Rhopalosiphum rufulum	8	...	...	...	...	...	11
Roepkea marchali	12	...	...	...	...	...	16,17
Rungsia kurdjumoui	6	...	...	...	...	...	17
Sacchiphantes abietis	18	...	...	...	...	...	17
S. laricifoliae	20	...	...	...	...	...	17
S. viridis	18	16	...	...	...	$14A+X_1X_2O$ male	17

Table 1—(Cantd.)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	temale	male	M. I	M. II	M. I		
Semiaphis (Hayhurstia) atriplicis	14	...	...	...	...	...	17
S. (Neohaihurstia) tataricae	14	...	...	...	...	...	17
Sappaphis piri	12	...	...	...	...	...	16,17
Schizaphis graminum	8	...	...	...	...	...	17,25,29
Schizolachnus pineti	18	...	...	...	...	...	17
Schizoneura subelliptica	12	...	...	...	12	...	19
S. ulmi	12 ?	...	...	...	...	...	19
Shivaphis celti	6*	5*	3	...	...	XO male	17,19
Sipha agropyrella (kurdjumoui)	6	...	...	...	...	...	29
	6	...	...	...	...	...	25
S. glyceriae	12	...	...	...	...	...	11
Sitobion avenae	18	...	...	...	...	...	17
Sitobion fragariae	18	...	...	...	...	...	17
S. luteum	12	...	...	...	...	...	11
Solidago altissima	12*	11*	6	5,6	...	XO male	19
Stomaphis janonis	10	8	...	...	...	$6A+X_1X_2O$ male	17
Stomaphis yonois	20*	18*	10	8,10	...	X_1X_2O male	19
Subsaltusaphis oranata	8	...	...	...	...	...	11
Symydobius kobae	26	25*	13	...	...	24A XO male	17,19

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
S. oblongus	16	...	...	...	...	...	11
Tamalia coweni	6	5	...	...	...	4A+XO male	17
Tetraphis betulina	12	...	...	...	...	...	17
Tetraneura ulmi	14	13	13	7	...	XO male	19,17,26
Thelaxes dryophila	8	...	...	...	...	...	17
Thecabius lysimachiae	18	...	...	...	...	...	11
T. populiconduplifolius	28	...	...	...	...	...	12,17,18
Therioaphis riehmi	16	...	...	...	...	...	17,25
T. shinal	14*	13*	7	...	...	XO male	19
Tinocallis ulmifolii	8	...	...	...	...	...	17,25
Tiliaphis shinae	14	...	...	...	...	...	17
Toxoptera aurantiae	8	...	...	...	...	...	17
Toxopterella drepanosiphoides	12	...	...	...	...	...	16,17
Tuberculatus kashiwae	14	13*	7	...	...	12A+XO male	17,19
T. quercicolus	14	13*	7	...	...	12A+XO male	17,19
Tuberolachnus salignus	8	...	...	...	...	...	17
T. viminalis	8*	7*	4	...	...	...	19
Uroleucon grossum	12	...	...	...	...	...	11
U. hypochoeridis	12	...	...		...	...	11

Table 1—(*Contd.*)

Name of the species	Diploid No.		Spermatoc.		Oocy.	Remarks	Ref. No.
	female	male	M. I	M. II	M. I		
U. jaceicola	12	...	...	...	...	...	11
U. tanaceti	12	...	...	...	...	...	11
Utamphorophora crataegi	10	...	...	...	...	...	17,25
Vesiculaphis theobaldi	40	...	...	...	...	...	11
Viteus vitifolii	10	9*	...	...	...	8A+XO male	17
Xerophylla caryaecaulis	8	6	...	...	...	$4A+X_1X_2O$ male	17
Xe. caryaefallax	12	...	...	...	...	...	17
Xe. caryaeglobuli	22	...	...	...	...	...	17
Xe. depressa	6	...	...	...	...	...	17
Xe. globosa	6	...	...	...	...	...	17
Xe. subelliptica	6	...	...	...	...	...	17
Xerophyllus sp.	12	...	...	...	...	...	17

in speciation of aphids is not to be ignored because thelytokous reproduction might lead to polyploidy without series handicap (White, 1973). Thus the thelytoky, the spontaneous occurrence of polyploid nuclei in diploid individuals, the existence of multiple sex chromosome mechanism might support the role of polyploidy in the speciation of aphids. However, the present state of knowledge of cytology would not help to come to any definite conclusion but it certainly indicated a number of avenues for its application to cytotaxonomy, in bringing out inter-relationships between genetic systems of aphids and coccids as well as the genetic system of its own and so on. The cytology has made its mark in solving taxonomic hurdles in species of the genera *Myzus* (Blackman, 1971; Blackman and Takada, 1977), *Euceraphis* (Blackman, 1977) and *Amphorophora* (Blackman, Eastop and Hills, 1977).

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ADDENDUM

New records of chromosome numbers appeared in the following Abstract Nos of the Symposium on "Recent trends in Aphidological strudies", Utkal University, Bhubaneswar, June 9-12, 1979.

Abstract No. 82—Kurl, S. P. and Misra S. D., Karyological studies in two species of aphids. p. 46.

Abstract No. 83—Khuda-Bukhsh, A. R., Chromosomes of three species of *Aphis*. p. 46.

Abstract No. 84—Mishra, S. D. and Kurl, S. P., Variation in chromosome number in *Myzus persicae* (Sulzer). p. 47.

The Aphids : *194.201*

KARYOLOGICAL STUDIES IN TWO SPECIES OF APHIDS

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ABSTRACT

The chromosomes of *Dactynotus* (*Uromelan*) *compositae* (Theobald) and *Macrosiphum* (*Sitobion*) *rosaeformis* Das have been described.

INTRODUCTION

Gut (1976) estimated that the cytology of about 8.5 % species of the aphid world fauna is known only by their chromosome numbers. Among the 653 Indian aphid species estimated by Ghosh (1977) Kurl and Misra (1978) worked out that only 1.37 % viz., 9 species are known for their chromosome number alone and those are *Aphis craccivora* (Koch) and *A. nerii* Boyer (Misra & Parida, 1975); *A. gossypii* Glover and *Rhopalosiphum maidis* (Fitch) (Pradhan & Parida, 1976); *Neotheriaphis chhenafuli* Behura & Dash (Dash & Behura, 1976); *Rhopalosiphum nymphaeae* (L.) (Behura & Bohidar, 1978); *Lipaphis erysimi* (Kalt.) and *Brachyunguis calotropicus* Menon & Pawar (Kurl & Misra, 1978) and *Macrosiphoniella sanbornii* (Gillette) (Khuda-Bukhsh & Dutta, 1978).

The present paper deals with the number, morphology and metrical data of somatic chaomosomes of *Dactynotus* (*Uromelan*) *compositae* (Theobald) and *Macroiphum* (*Sitobion*) *rosaeformis* Das studied for the first time.

In the genus *Dactynotus* over two dozens of species (Shinji, 1931; Sun & Robinson, 1966; Olive, 1967; Robinson & Chen, 1969; Kuznetsova & Shaposhnikov, 1973) and in the genus, *Macrosiphum* over 1 dozen of species (Stevens, 1906; Shinji, 1961; Lawson, 1936; Sun and Robinson, 1966; Steffan, 1968; Robinson & Chen, 1969; Gut, 1976) are chromosomally known from the study of mostly the somatic tissues, rarely the germinal tissues.

MATERIALS AND METHODS

The following two species of aphids were collected from different host plants in different localities in and around Jodhpur :—

Dactpnotus (*U.*) *compositae* from host plant *Centaurea moschata* (Family — Compositae)

Macrosiphum (*S.*) *rosaeformis* from host plant *Rosa indica* (Family — Rosaceae)

Specimens in the feeding condition were brought to the laboratory and young embryos with undeveloped eye pigmentation were dissected out from the apterous viviparous parthenogenetic females. From these embryos permanent preparations were made following the air-dry method of Kurl & Narang (1978) using Giemsa stain. For metrical data well spread metaphase spreads were selected and the actual lengths of chromosomes were measured with the oculometer. Later on the photomicrographs were taken. Projections of the photomicrographs with the help of an epidiascope were then traced on a white paper with a sharp pencil for determination of the relative percentage length of each chromosome. The mean values for all the chromosomes of each species were finally expressed in relative percentages. The chromosomes were numbered in decreasing order of their length and homologous pairs were selected for karyotypic construction.

OBSERVATIONS

At the metaphase stage the diploid chromosome number in the two species viz., *D.* (*U.*) *compositae* and *M.* (*S.*) *rosaeformis* was found to be 12 and 18 respectively (Figs. 1 and 3). In *D.* (*U.*) *compositue*, out of 144 will-spread metaphase plates examined, 96 contained 2n = 12 while the rest of the plates had aneuploid and polyploid numbers. In *M.* (*S.*) *rosaeformis* 47 metaphase plates out of the 84 plates studied, showed 2n = 18 chromosomes and the rest had aneuploid numbers.

No heterochromatin body was observed during interphase. Prophase chromosomes appeared as irregularly twisted threads. In prometaphase the chromosomes were long and took light stain. In a few late prophase chromosomes clear G-band like structures were observed. At metaphase the chromosomes were more condensed, short, rod shaped and darkly stained elements (Figs. 1 and 3). No anaphase and telophase could be observed. In both the species the chromosomes were rod shaped, of different sizes, evenly stained and without clear kinetochore or primary constriction indicating their holocentric nature.

TABLE

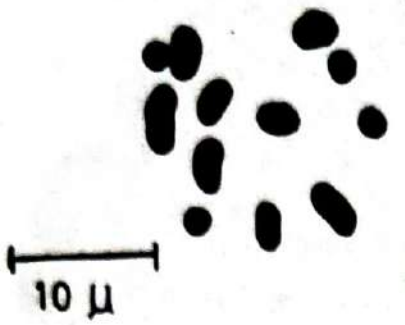
Lengths in micra and relative lengths as
of two species

Species & No. of somatic figures analysed	Mean TLC microns		Mean chromosome						
			Chromosome						
			1	2	3	4	5	6	7
Dactynotus	42.17 µ		5.27	5.22	4.55	4.55	3.88	3.88	3.48
(***Uromelan***)	±1.97	SE	0.21	0.20	0.20	0.20	0.22	0.22	0.18
compositae		%	12.76	12.09	10.60	10.08	9.29	8.83	8.55
16		SE	0.30	0.31	0.19	0.16	0.17	0.11	0.15
Macrosiphum	44.32 µ		5.14	5.14	2.92	2.92	2.64	2.64	2.42
(***Sitobion***)	±1.32	SE	0.56	0.56	0.48	0.48	0.35	0.35	0.21
rosaeformis		%	10.81	10.18	6.00	5.77	5.36	5.32	5.20
10		SE	0.17	0.17	0.21	0.16	0.07	0.06	0.06

1

percentage of TLC of metaphase chromosome of aphids.

length										
number										
8	9	10	11	12	13	14	15	16	17	18
3.48	2.00	2.00	1.91	1.91						
0.18	0.13	0.13	0.12	0.12						
7.82	5.54	5.12	4.80	4.41						
0.19	0.17	0.16	0.16	0.15						
2.42	2.14	2.14	1.85	1.85	1.85	1.85	1.60	1.60	1.60	1.60
0.21	0.25	0.25	0.21	0.21	0.21	0.21	0.15	0.15	0.15	0.15
5.07	5.05	4.92	4.89	4.85	4.73	4.63	4.45	4.39	4.36	3.88
0.03	0.03	0.03	0.04	0.04	0.05	0.03	0.00	0.01	0.04	0.10



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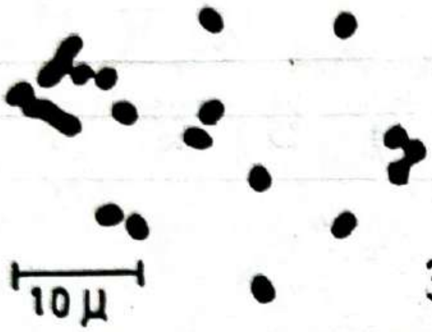

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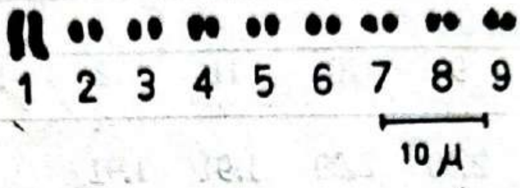

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Fig. 1—Photomicrograph of somatic chromosomes of *Dactynotus (U.) compositae*, 2n = 12.

Fig. 2—Karyotype prepared from Fig. 1.

Fig. 3—Construction from photomicrograph of somatic chromosomes of *Macrosiphum (S.) rosaeformis*, 2n = 18.

Fig. 4—Karyotype prepared from Fig. 3.

The relative percentage lengths and the actual lengths in micra of the somatic metaphase chromosomes of the two species are given in Table 1.

At prometaphase the chromosomes are extraordinarily lengthy. In *D. (U.) compositae* at prometaphase the actual lengths of chromosomes range from 2.14 to 7.15 micra while in *M. (S.) rosaeformis* they range from 2.86 to 10.01 micra.

In *D. (U.) compositae* the actual lengths of the haploid number of chromosomes at metaphase are 4.29, 3.57, 2.86, 2.86, 1.43 and 1.43 micra with the mean length 2.74 micra while in *M. (S.) rosaeformis* the lengths are 5.14, 2.92, 2.64, 2.42, 2.14, 1.85, 1.85, 1.60 and 1.60 micra and the mean length is 2.46 micra. The total complement length (TLC) in *D. (U.) compositae* and *M. (S.) rosaeformis* is 44.13 and 44.32 micra respectively (Table 1).

Chromosomes having similar lengths were matched as homologoues and the karyotypes were constructed (Figs. 2 & 4). In *D. (U.) compositae* there were one pair long, three pairs medium and two pairs short sized chromosomes. The longest chromosome was approximately 3 times more than the shortest. In *M.* (*S.*) *rosaeformis* one pair was long and the remaining eight were short pairs. The longest is nearly 3.5 times bigger than the shortest.

DISCUSSION

Over 2 dozens of species of *Dactynotus* examined by different workers most of them have 2n = 12 chromosomes and very few have 2n = 10. The chromosome number and grouping determined in *D.* (*U.*) *compositae* (Fig. 2) agree considerably with that of earlier reports of Olive (1967) and Robinson & Chen (1969).

M. (*S.*) *rosaeformis* has diploid chromosome number of 18. Only one other species, *M. avenae* (Fabricius) has 2n = 18 chromosomes (Robinson & Chen, 1969). Most of the other species of *Macrosiphum* have 2n = 10 chromosomes. In *M.* (*S.*) *rosaeformis* there is only one long pair of chromosomes, the remaining eight form 4 short pairs which are of about the same size (Fig. 4). The chromosome lengths of *M. avenae* as shown in idiogram (Robinson & Chen, 1969) are similar to that of *M.* (*S*) *rosaeformis.*

The chromosomes of Homoptera and Heteroptera are known either to have a diffuse centromere activity or are holocentric (Schrader, 1935; Hughes-Schrader & Ris, 1941; Hughes-Schrader, 1948; Hughes-Schrader & Schrader, 1961 and White, 1973) which is also found in both the species.

As the aphid chromosomes lack distinct morphological features, Harper & MacDonald (1966) and Olive (1967) suggested that a comparison of karyotypes may not be helpful in differentiating two species within a genus. The measurements of relative lengths and areas of the somatic chromosomes if compared could show the distinction which has been followed in the present study (Table 1).

Sun & Robinson (1966) suggested that the primitive number of aphid chromosomes may be 2n = 8 and that species with 6, 10, 16 and 18 chromosomes may represent the end products of evolutionary processes resulting either from fusion or fragmentation. The variation in chromosome count in most of the metaphase figures in both the species, is common. Asynchronous division of the chromosomes in some species (Cognetti, 1961) and rupturing of the cells due to longer hypotonic treatment are considered as the sources of the aneuploid numbers. The aneuploid karyotypes may have evolved by fragmentation of chromosomes due to their holokinetic nature of chromosomes (Kuznetsova, 1974).

There is as yet no agreement on using the chromosome numbers as the criteria of their primitiveness or otherwise. Further studies are in progress.

ACKNOWLEDGMENTS

Our grateful thanks are due to Prof. D. N. Raychaudhuri, Calcutta University, Calcutta and the Director, Z. S. I. Calcutta for identification of the aphid species. One of us (SPK) is thankfull to U. G. C. for the award of Teacher Research Fellowship.

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The Aphids : 202-209

VARIATION IN CHROMOSOME NUMBER IN *MYZUS PERSICAE* (SULZER)

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ABSTRACT

The chromosome number in *Myzus persicae* (Sulzer) is 2n = 12. But 2n = 10 and 2n = 11 clones are also found.

INTRODUCTION

The green peach aphid, *Myzus* (*Nectarosiphon*) *persicae* (Sulzer) in India is a major polyphagous species infesting mainly *Pisum sativum*, *Nicotiana tabacum*, *Solanum tuberosum*, many cruciferous vegetables and garden plants. Under Indian climatic conditions, *M. persicae* (Sulzer) persists as a parthenogenetic, viviparous form throughout the year (Anholocyclic life cycle), but Ghosh & Raychaudhuri (1962) reported its sexual form from Delhi. Shinji (1941) was first to report 2n = 12 chromosome in *M. persicae* and later, Colling (1955) from Britain and Sun & Robinson (1966) from Canada. But Cognetti (1961) reported 2n = 14 chromosomes in *M. persicae* from Italy which was confirmed from India by Sethi & Nagaich (1972). Dionne & Spicer (1957) published the karyotype and Robinson & Chen (1969) the idiogram of this species as 2n = 12. However, Blackman (1971) made an extensive study and reported the chromosomal abnormalities in an anholcyclic biotype of *M. persicae* with 2n = 12, 13 and 14 chromosomes. Clones with 13 and 14 chromosomes appeared to be distinct The anholocylic biotype was separable from the normal 12-chromosomes form by slight but consistent morphological differences. Blackman & Takada (1975) later discovered a particular translocation between autosomes 1 and 3 in a heterozygous glass house population of *M. persicae* in Britain. The similar identical translocation was subsequently found commonly in field populations of *M. persicae* in many parts of the world except India (Blackman *et al.*, 1978).

The present paper deals with chromosomal abnormalities in different anholocyclic forms of *M. persicae* which seem to be separate biotypes. The somatic chromosome number in three biotypes varied as 2n = 10, 11 and 12, origin of which have been discussed.

MATERIALS AND METHODS

Specimens were collected from buds, flowers and leaves of different host plants in and around Jodhpur during January-February 1979 as follows :—

Biotype	Host-plant	
I	***Pisum sativum***	(Family-Papilionaceae)
	Coriandrum sativum	(Family-Umbelliferae)
II	***Antirrhinum majus***	(Family-Scrophulariaceae)
	Lineria vulgaris	(Family-Scrophulariaceae)
III	***Phlox drumondi***	(Family-Polemoniaceae)

Young embryos indicating undeveloped eye pigmentation were dissected out from the apterous viviparous parthenogenetic females and cytological preparations were made following the air-dry method (Kurl & Narang, 1978) using Giemsa stain (10% in phosphate buffer at pH 6.8). The metrical data were taken as described elsewhere (Kurl & Misra, 1979).

OBSERVATIONS

At the metaphase stage the diploid chromosome number in the three biotypes I, II and III was found to be 12, 11 and 10 respectively (Figs. 1, 3, 5). Out of the total 271 metaphase plates examined 8.48% had 2n = 10, 56.08% had 2n = 11 and 35.42% had 2n = 12 chromosomes.

In all the three karyotypes, the actual lengths and the relative percentage lengths of all the chromosomes were measured (Table 1) and homologised by the lengths. Thus the normal and abnormal karyotypes were constructed (Figs. 2, 4, 6). No heterochromatin body was observed in the interphase nuclei of all biotypes. The mean length of chromosomes in biotypes I, II and III ranged between 3.57 and 10.01 micra; 2.86 and 14.30 micra and 1.43 and 5.72 micra respectively.

2n = 12 chromosomes must be regarded as the normal karyotype because all the chromosomes could be arranged in homologous pairs based on their actual lengths and relative percentage lengths. The females are with XX sex mechanism (White, 1973) and the longest homologous pair has been suspected as the sex chromosomes in females (Blackman, 1971 and Blackman & Takada, 1975).

The total complement lengths (TCL) in three karyotypes I, II and III are 42.92, 41.39 and 32.14 respectively.

DISCUSSION

The normal female karyotype of ***M. persicae*** found as 2n = 12 by the earlier workers (Colling, 1955; Sun & Robinson, 1966; Blackman, 1971) is confirmed by us (Fig. 2). During the course of present study the embryonic tissues had also complement of 11 (Fig. 3) or 10 chromosomes (Fig. 5). Karyotype of 2n = 11 differed from that of 2n = 12 in having a long unpaired chromosome (No. 6) (Fig. 4) in place of the shortest pair of chromosomes (Fig. 2), while karyotype 2n = 10 appeared to have four homologous pairs and two unpaired elements-No. 5 and 6 (Fig. 6).

The odd number of chromosomes was found in autumn. Sexuals might have been produced by viviporous parthenogenetic famales. One might then accidentaly deal with a male embryo in which a somatic chromosome number is supposed to be 2n—1 (XX ♀ and XO ♂ system in aphids), so that an odd chromosome number may be found in one biotype. It is not possible to identify the sex of an embryo. Cells from embryos may be identified by the use of phase contrast microscope. Since female cells have dense heterochromatin body, they are different from males. The only way to establish this karyotype (2n = 11) is to compare the relative percentage lengths of chromosomes of this with that of the normal karyotype (2n = 12). On comparision we found that the metrical data of the two do not coincide with each other. The possibility of karyotype 2n = 11 to be the male is ruled out. If the chromosome No. '6' in Fig. 4 is conjectured to be 'X' supposing that it is from a male embryo, this particular chromosome should be present in duplicate in normal female (XX) (Fig. 2), but clearly it is not the case here. The second possibility is that the unpaired element (No. 6) in this karyotype may have been formed by the fusion of the two shorter chromosomes, since the fusion mechanism is very common in aphids.

From the figures it seems likely on the contrary that it might apparently be a case of fusion, presumably of the 3rd or 4th pair of chromosomes in Fig. 2. A critical metrical analysis is necessary to make a reasonably accurate conjecture. This makes us to conclude that the karyotype $2n = 11$ may have resulted from the fusion of two shorter chromosomes from a female karyotype ($2n = 12$).

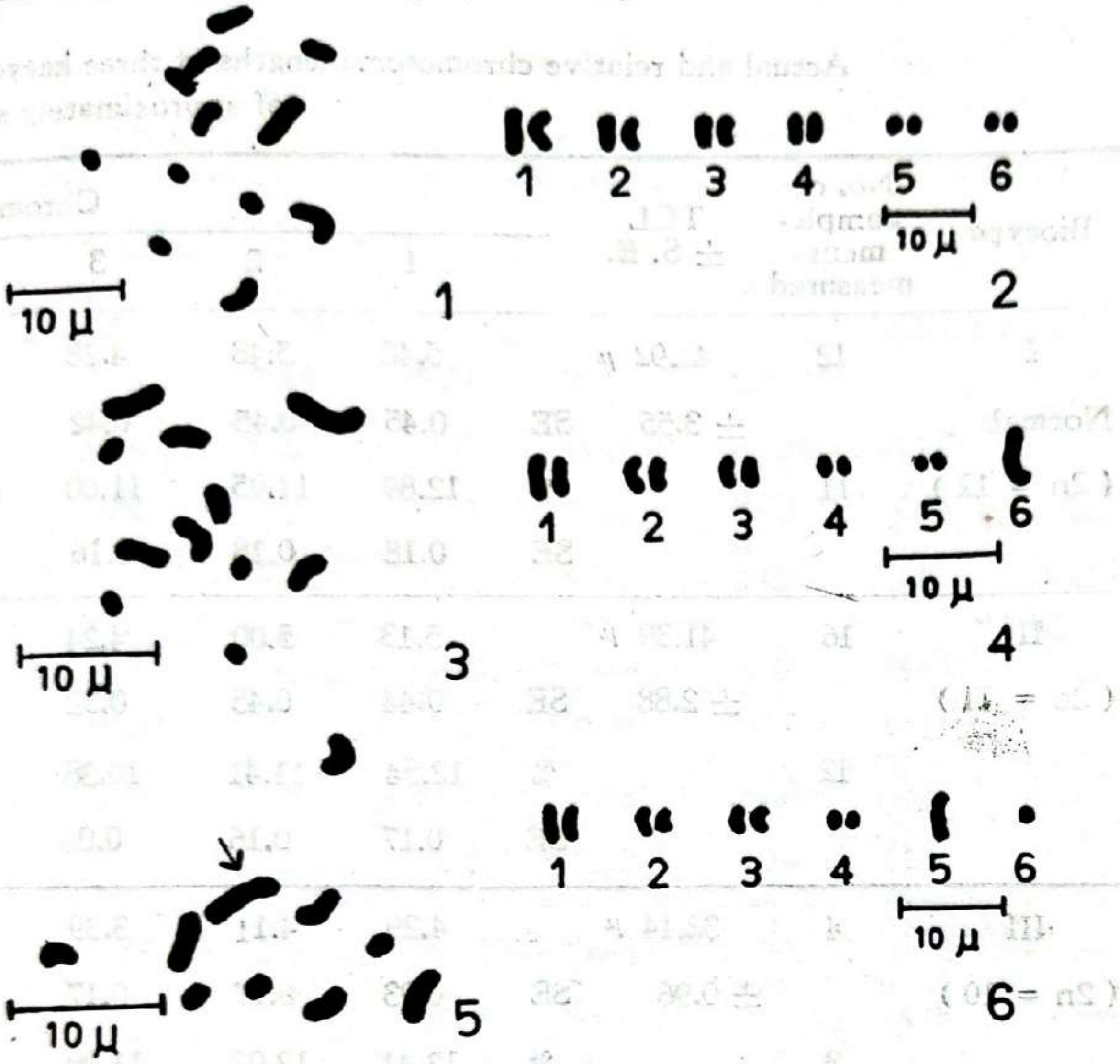

Fig. 1—Somatic metaphase of female *M. persicae*, $2n = 12$ (Normal).
Fig. 2—Karyotype constructed from Fig. 1.
Fig. 3—Somatic metaphase of *M. persicae*, $2n = 11$ (Abnormal)
Fig. 4—Karyotype constructed from Fig. 3.
Fig. 5—Somatic metaphase of *M. persicae*, $2n = 10$ (Abnormal), arrow shows secondary constriction.
Fig. 6—Karyotype constructed from Fig. 5.

On comparing the normal karyotype ($2n = 12$) with that of $2n = 10$, it is clear that the latter has four homologous pairs and two unpaired elements No. '5' and '6' (Fig. 6). Here again $2n = 10$ karyotype seems to have originated from the normal karyotype ($2n = 12$) by the process of fusion.

TABLE

Actual and relative chromosome lengths of three karyotypes of approximately similar

Biotype	No. of comple-ments measured	TCL ± S. E.		Chromosome 1	2	3	4
I	12	42.92 μ		5.48	5.48	4.28	4.28
Normal		± 3.55	SE	0.45	0.45	0.42	0.42
(2n = 12)	11		%	12.89	11.95	11.00	10.03
			SE	0.18	0.18	0.16	0.13
II	16	41.39 μ		5.13	5.00	4.24	4.10
(2n = 11)		± 2.88	SE	0.44	0.45	0.32	0.33
	12		%	12.54	11.41	10.38	10.01
			SE	0.17	0.16	0.06	0.10
III	4	32.14 μ		4.29	4.11	3.39	3.39
(2n = 10)		± 0.96	SE	0.03	0.17	0.17	0.17
	3		%	13.41	12.02	11.00	10.51
			SE	0.57	0.62	0.63	0.26

1

in ***Myzus persicae***, assuming chromosome lengths to be homologous.

number							
5	6	7	8	9	10	11	12
3.51	3.51	3.21	3.21	2.02	2.02	1.96	1.96
0.34	0.34	0.25	0.25	0.16	0.16	0.17	0.17
9.23	8.85	8.50	8.01	5.42	4.98	4.69	4.36
0.12	0.09	0.10	0.13	0.12	0.09	0.10	0.19
3.66	3.66	2.31	2.31	2.14	2.14	6.70	—
0.25	0.25	0.10	0.10	0.08	0.08	0.54	—
9.59	8.89	6.84	5.91	5.65	5.03	14.28	—
0.11	0.11	0.28	0.15	0.12	0.14	0·21	—
2.86	2.68	2.14	1.96	5.36	—	1.96	—
0.00	0.17	0.00	0.16	0.20	—	0.16	—
9.82	9.37	6.77	6.11	15.14	—	5.75	—
0.15	0.13	0.24	0.22	0.67	—	0.30	—

At the moment, we can not make any explanation for this abnormal karyotype. However, the possibility for these abnormal karyotypes due to the effects of insecticides sucked through the plant sap can not be ruled out (Blackman *et al*., 1978).

Since the slides were made from smears by air-dry method using hypotonic solution, there may be some chances of the chromosomes having been disturbed or dislodged but this possibility is ruled out because only those metaphase plates were selected which showed spindle material round the chromosome set. Although clear phenotypic differences between individuals with normal and abnormal karyotypes have been reported (Blackman, 1971) irrespective of the colouration of the individuals no morphological difference was observed in our materials with 2n = 12, 2n = 11 and 2n = 10 chromosomes. Thus, the occurrence of chromosomal differences does not necessarily make the species different, just as the similar number of chromosomes in two individuals do not necessarily make them conspecific.

ACKNOWLEDGMENTS

The authors are grateful to Dr. N. C. Pant, Director, Commonwealth Institute of Entomology, London for the identification of aphid species. One of us (SPK) is also thankful to the U. G. C. for the award of Teacher Research Fellowship.

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The Aphids : 210-213

CHROMOSOMES OF THREE SPECIES OF *APHIS*

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ABSTRACT

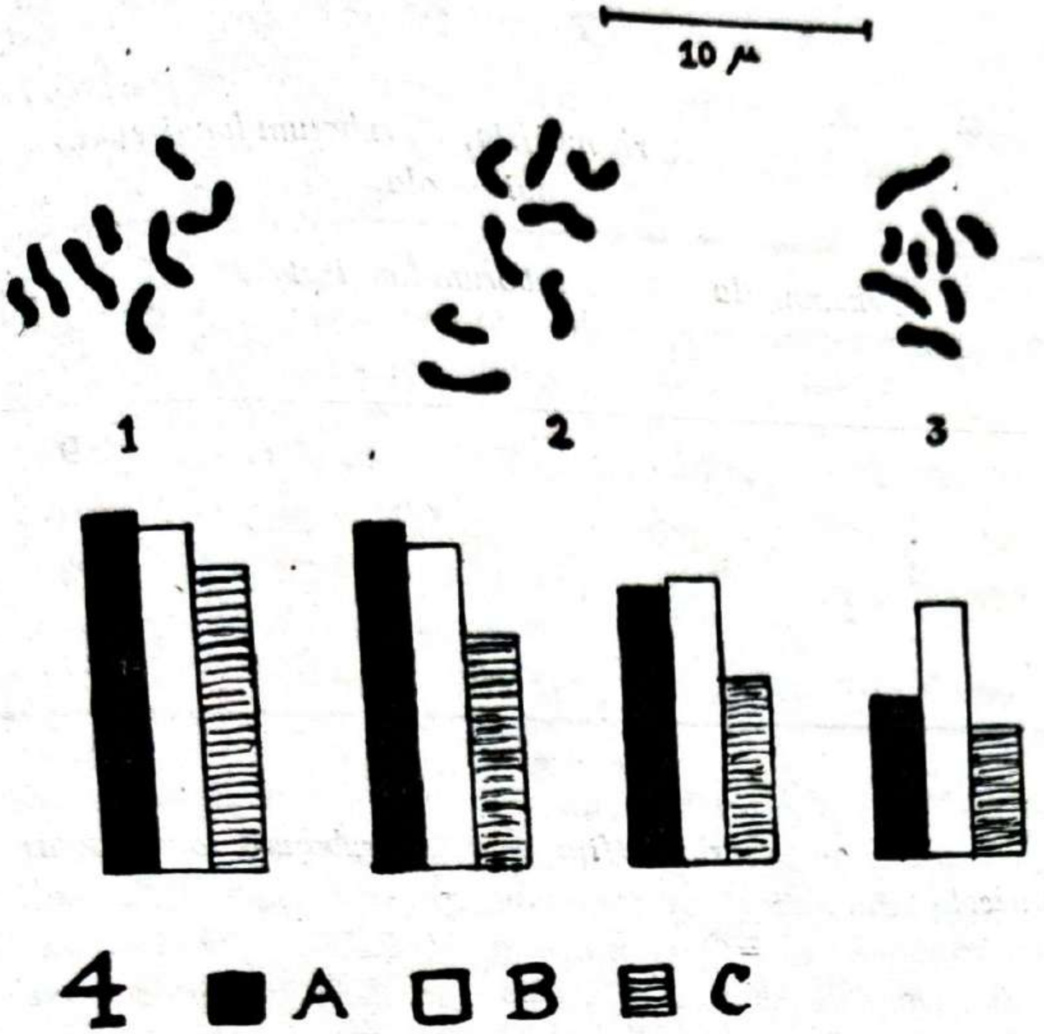
Chromosomes of *Aphis rhamnifila, A. ruborum longisetous* and *A. spiraecola* have been described.

INTRODUCTION

Of about 4,000 species of aphids hitherto taxonomically described, only some 398 odd species have been cytologically studied throughout the globe (Kuznetzova and Shaposhnikov, 1973; Gut, 1976; Manna, 1983). Further, from India out of the 653 species taxonomically recorded (Ghosh, 1977) only 11 species have so far been cytologically investigated (Behura, 1978; Kurl and Misra, 1978; Manna, 1983). The present wook was therefore undertaken to add further knowledge to the cytology of Indian aphids.

Apterous viviparous females of three species of *Aphis*, viz., *rhamnifila* David, Narayanan and Rajasingh, *ruborum longisetosus* Basu, and *spiraecola* Patch, were collected from the host plants *Rhamnus virgatus* (Fam : Rhamnaceae), *Rubus ellipticus* (Fam : Rosaceae) and *Cestrum nocturnum* (Fam : Solanaceae) respectively at Mussoorie, U. P. during May and their early embryos were subjected to a modified squash method (Khuda-Bukhsh and Datta, 1979) for the study of their somatic chromosomes.

The diploid metaphase complements in all the three species, viz., *A. rhamnifila* (Fig. 1), *A. ruborum longisetosus* (Fig. 2) and *A. spiraecola* (Fig. 3), contained 8 chromosomes which measured between 3.4 and 1.6 micra, 3.3 and 2.5 micra and 2.9 and 1.3 micra respectively (Table 1). Since all of them had the same diploid number, attempts have been made to compare the metrical data (Table 1) and the idiograms (Fig. 4 A-C)



Figs. 1-4 : Camera lucida drawing of metaphase complements in
1—*A. rhamnifila* Iidogram of 4A—*A. rhamnifila*
2—*A. ruborum longisetosus* 4B—*A. ruborum longisetosus*
3—*A. spiraecola* 4C—*A. spiraecola.*

of these three species to see if some difference between the species could be substantiated. A comparison of the idiograms (Fig. 4 A-C) and the analysis of the metrical data (Table 1) would show that the chromosomes in all the three species were gradually seriated except Nos. 3 and 4 in *A. rhamnifila* which had conspicuous difference between them. The minimum difference between any two adjacent chromosomes was noted between No 1 and 2 in *A. rhamnifila.* If the relative percentage lengths in these three species are compared, it would show that the 4th chromosome in *A. rhamnifila* was palpably smaller than that in *A. ruborum longisetosus*, but not much strikingly dissimilar from that in *A. spiraecola.* Similarly, the chromosome No. 1 in *A. spiraecola* was larger in relation to its absolute length of genome than its counterpart in *A. ruborum longisetosus.*

TABLE 1

Mean length in micra, relative percentage length (R_L) of chromosomes in *A. rhamnifila*, *A. ruborum longisetosus* and *A. spiraecola*.

Chrom. No.	*A. rhamnifila* Mean length in micra	R_L	*A. ruborum longisetosus* Mean length in micra	R_L	*A. spiraecola* Mean length in micra	R_L
1.	3.4	30.9	3.3	28.2	2.9	35.3
2.	3.3	30.0	3.1	26.5	2.3	28.0
3.	2.7	25.5	2.8	23.9	1.7	20.7
4.	1.6	14.5	2.5	21.4	1.3	15.9

As far as the present author is aware, this is the first report on the chromosomes of *A. rhamnifila* and *A. ruborum longisetosus* though *A. spiraecola*, the other species under present study, had earlier been reported to have 2n = 8 chromosomes (Robinson and Chen, 1969). About 36 identified species of *Aphis*, including the present ones, have so far been cytologically studied (Kuznetzova and Shaposhnikov, 1973; Gut, 1976; Ghosh, 1977; Behura, 1978; Manna, 1983; Rabinson and Chen, 1969) and except in 5 species all others have been found to contain 8 chromosomes in their diploid complements (Manna, 1983). Thus the genus *Aphis* seems to be characterized by the stable number of 8 chromosomes although distinctness between one species and the other could be drawn by analyzing their metrical data and relative percentage length of the chromosome complements. As such structural rearrangements of some form of mutual exchange could be contemplated in the evolution of karyotypes in these three species of *Aphis* as has not also been suggested for other species of aphids (Gut, 1976; Rohinson and Chen, 1969;

ACKNOWLEDGMENTS

The author is highly indebted to Prof. G. K. Manna, National Fellow, and Prof. A. K. Bose, Head, Deptt. of Zoology, Kalyani University for encouragements and laboratory facilities. Sincere thanks are due to Dr. Samiran Chakraborti, Deptt. of Zoology, Kalyani University for identification of the specimens. Financial help from the University of Kalyani for this work is gratefully acknowledged.

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THE DIPLOID CHROMOSOMES IN THE GENUS *RHOPALOSIPHUM*

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ABSTRACT

The diploid chromosome number in the different species of *Rhopalosiphum* has been reported to be 6 in *pseudobrassicae*; 8 in *cerasifoliae, maidis, padi* and *prunifoli*; 10 in *insertum* and 16 in *nymphaeae* indicating thereby that the genus forms chromosomally a heterogenous group. Species with the lowest chromosome number e.g., $2n=6$ have sizes of chromosomes relatively larger than those with $2n = 16$ chromosomes.

INTRODUCTION

Cytology—an useful additional tool in taxonomy of animals, is an established fact (Manna, 1969). The subfamily Aphidinae is cytologically characterized by the presence of one or more X chromosomes, no Y chromosome (Makino, 1956; Sun and Robinson, 1966), parthenogenetic life cycle and a wide range of diploid chromosome number in different species.

Table 1 shows the diploid chromosome number in seven species of the genus *Rhopalosiphum* studied by different workers among which we contributed one (Behura and Bohidar, 1978). The number varies through 6, 8, 10 and 16 but 8 is more prevalent. The metaphase complements of different species are not identical (Figs. 1-7). All the three pairs are of equal length in *R. pseudobrassicae* with 6 chromosomes; all the four pairs are almost of equal length in *R. prunifoliae* with 8 chromosomes; three pairs of equal length and one pair slightly shorter in *R. maidis* and *R. padi* with 8 chromosomes each; two pairs long and two pairs short in *R. cerasifoliae* with 8 chromosomes; three pairs long and two pairs very short in *R. insertum* with 10 chromosomes and two pairs long and six pairs short in *R. nymphaeae* with 16 chromosomes. Taking karyotypes into consideration, *R. maidis* and *R. padi* appear to be closely related. The number of short chromosome pairs increases with the increase in chromosome numbers. For example, in the species with $2n = 6$, there are no short pairs,

Figs. 1-7—Karyotype of different species of *Rhopalosiphum* :

(1) *cerasifoliae* (After Robinson & Chen, 1969).
(2) *insertus* (After Sun & Robinson, 1966).
(3) *maidis* (After Sun & Robinson, 1966).
(4) *nymphaeae* (Behura & Bohidar, 1978).
(5) *padi* (After Sun & Robinson, 1966).
(6) *prunifoliae* (After Fox, 1957).
(7) *pseudobrassicae* (After Fox, 1957).

in species with 2n = 8, the number varies from zero to two short pairs; in species with 2n = 10 there are two short pairs, and in species with 2n = 16 there are four short pairs.

From a study of the relative length of the karyotypes it appears that species with the lowest chromosome number as in *R. pseudobrassicae* (2n = 6) are characterized by large chromosomes and species with highest chromosome number as in *R. nymphaeae* (2n = 16) have the smallest chromosomes. Sun and Robinson (1966) also hold the same view.

Thus it appears that the species under the genus *Rhopalosiphum* differ from each other cytologically so far as the number of diploid chromosomes and their relative lengths are concerned.

TABLE 1

Diploid chromosome number of 7 species of ***Rhopalosiphum*** reported by different workers.

Name of species	Chromosome number (2n)	Reported by
1. *R. cerasifoliae* (Fitch)	8	Robinson and Chen, 1969.
2. *R. insertum* (Sanderson)	10	Sun and Robinson, 1966.
3. *R. maidis* (Fitch)	8	Sun and Robinson, 1966.
4. *R. nymphaeae* (Linnaeus)	16	Behura and Bohidar, 1978.
5. *R. padi* (Linnaeus)	8	Sun and Robinson, 1966.
6. *R. prunifoliae* (Fitch)	8	Fox, 1957.
7. *R. pseudobrassicae* (Davis)	6	Fox, 1957.

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V. APHIDS IN AGRICULTURE

INTERACTION BETWEEN APHID CLONES, PRE-ACQUISITION FASTING AND ACQUISITION FEEDING PERIODS AND VIRUS STRAINS ON THE APHID TRANSMISSION OF POTATO VIRUS Y

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ABSTRACT

Interaction between aphid clones, pre-acquisition fasting, acquisition feeding periods and two strains of potato virus Y (PVY) were studied employing *Aphis gossypii* (Glover) / *Myzus persicae* (Sulzer) to assess their role in governing an aphid's vectorial ability. Different aphid clones varied in their transmission ability, however, strain PVY^4 was transmitted more efficiently than PVY^2. One or 2 hrs. pre-acquisition fasting and acquisition feeding of 1 to 5 min. and transmission feeding upto 30 min. were beneficial for transmission but prolonged starvation and feedings had no or an adverse effect. Late stage nymphs were insignificantly superior over adult apterae and alatae. However, under all experimental combinations, the variables tried did not influence the relative transmission ability of an aphid clone indicating it to be a genetical character.

INTRODUCTION

Variations in the efficiency of different clones of a vector are well known since long. As early as 1931, Smith observed, "The question of the relationship of strains, biological races and varieties of insect vectors in regard to their ability to transmit viruses is a subject of great interest and one which up to the present has been much neglected" stands true till today. The wide differences between different species of aphids in transmitting virus are attributed to genetical characters. Variations in the transmission efficiency of the individuals within a species have been studied in detail with regard to circulative viruses (Stubbs, 1955; Bjorling and Ossiannilsson, 1958; Saksena, *et al.*, 1964; Rochow and Eastop, 1966; Bath and Chapman 1966; Upreti and Nagaich 1971a) and to some extent for stylet—borne viruses (Bawden and Kassanis, 1947; Nagaich *et al.*, 1970; Upreti and Nagaich, 1971b). It is known that inefficient transmitters for a virus may be efficient vectors for another virus and vice-versa. Experiments were, therefore, designed to elucidate the role of factors which apparently have a bearing on the transmission ability of different clones of ***M. persicae*** and ***A. gossypii***. Interactions between four factors viz., aphid clones, virus strains and fasting/feeding periods etc., were determined with regard to the efficiency of a vector clone for a virus strain and the observations are presented hereunder.

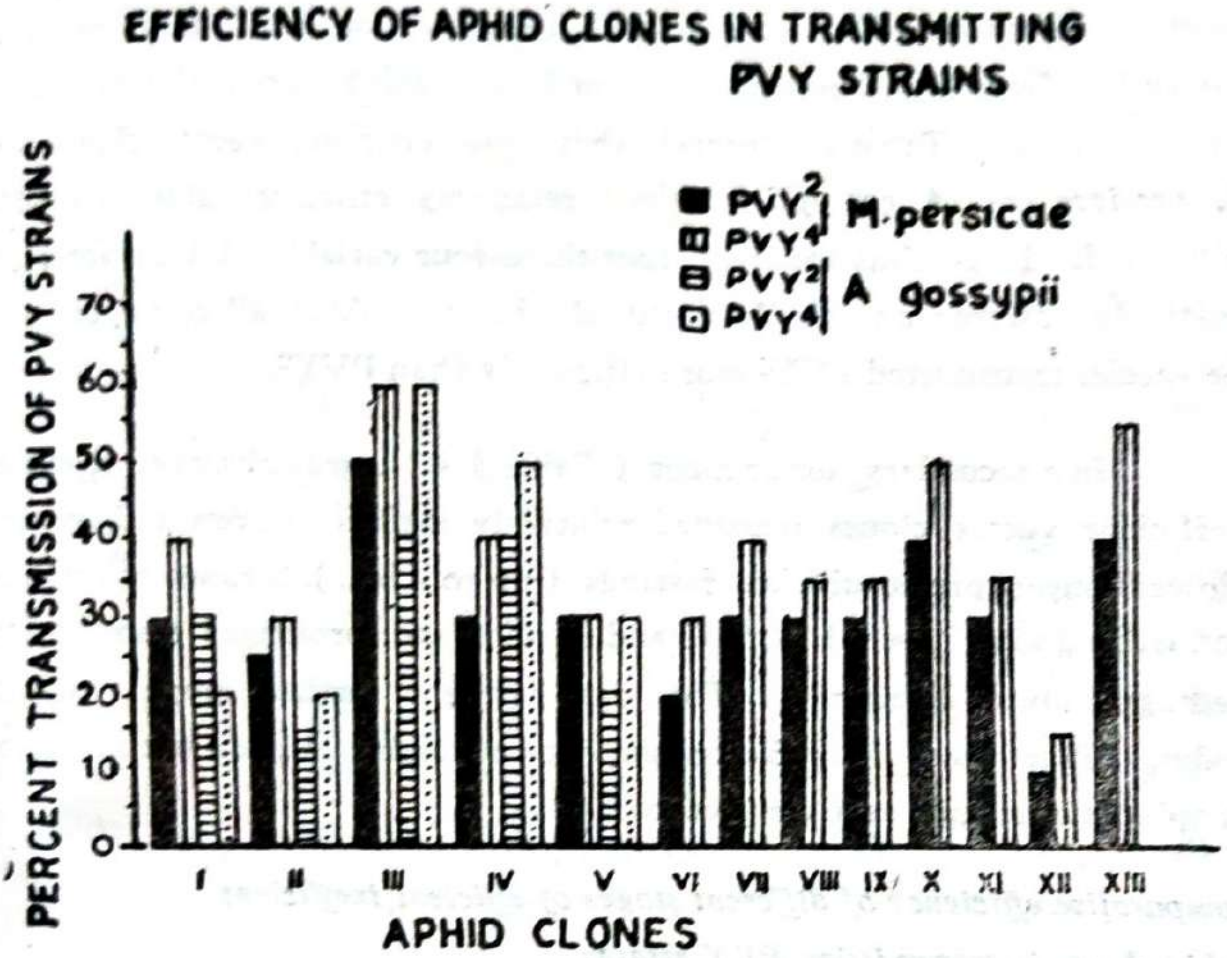
MATERIALS AND METHODS

Thirteen clones of ***M. persicae*** and five clones of ***A. gossypii*** were maintained individually on virus free/immune plants of cabbage/*Capsicum annuum* respectively. The cultures of PVY (strains PVY^2 & BVY^4) were maintained as described by Khurana *et. al.* (1975). All transmission tests were tried with viviparous apterous adults starved for 2 hrs. The virus cultures used throughout the investigations were three weeks old in source plant and normally the top 3rd/4th leaves were used for making the aphids viruliferous. Usually 1 to 2 hrs pre-acquisition fasting, 5 min acquisition access and 30 min of transmission feeding were allowed unless otherwise stipulated. All transmissions were tried to and from *Datura metel* plants which were grown singly in 4" earthen/plastic pots and maintained in an insect-proof glasshouse. All test plants were 4-5 weeks old and had 3-4 true leaves. Usually 5 aphids/test plant were used. Test plants were covered under small celluloid cages during the transmission feeding after which the aphids were killed. All experiments were repeated twice For each treatment a minimum of 10 test plants were employed. Adequate number of controls in all trials were exposed to non-viruliferous aphids from healthy *D. metel* plants but not even a single control plant was found to develop the infection.

RESULTS

Comparative vectorial efficiency of different clones :

The figure 1 reveals that a range of 10 to 60% transmission of PVY was achieved. Three and two clones of *M. persicae* and *A. gossypii* transmitted PVY^2 to the tune of 40% and more while, six and two clones efficiently transmitted PVY^4. It is also clear that all these clones transmitted PVY^4 more efficiently than PVY^2 except the *A. gossypii* clone 1.



Influence of fasting on aphid tranemission of PVY strains by different clones of A. gossypii and M. persicae :

Aphids of different clones of both the species were given a pre-acquisition fasting of 0, 1 and 2 hrs and then allowed 5 min acquisition and 30 min transmission feedings. The data embodied in Table 1 clearly reveal that although longer pre-acquisition fastings enhanced an aphid's virus vectorial ability irrespective of the virus strains, the efficient vector clones of either species remained relatively efficient over the inefficient ones.

Relation of the virus strains, aphid clones, pre-acquisition fasting and transmission feeding periods :

Since pre-acquisition fasting was found not to govern the efficiency of a vector, an experiment was designed to observe the interaction between a number of factors. To be sure whether or not these factors influence an aphid's uptake, carry over and inoculation ability, representative efficient and inefficient clones of ***M. persicae*** and *A. gossypii* were selected. They were allowed 0, 1 and 2 hrs starvation; 1 or 5 min. acqusition and uniform transmission feeding of 30 min using 5 aphids/plant. The data obtained (Table 2) reveal that the efficient vector clones of ***M. persicae*** and ***A. gossypii*** remained relatively efficient under all variables tried. It is thus apparent that these four variables did not interact positively towards an aphid's vectorial ability. Also all clones of both the species transmitted PVY^4 more efficiently than PVY^2.

In a secondary experiment (Table 3, 4) it was observed that the inefficient vector clones remained relatively inefficient even if they were allowed longer pre-acquisition fastings (up to 4 hrs.), a range of acquisition feeding viz., 30 sec. 1. 2, 5, 15 and 30 min, and prolonged transmission feedings (up to 24 hours). This data has lent further support to the findings that these four factors singly or in combination do not influence an aphid's efficiency as a virus vector.

Comparative efficiency of different stages of efficient/inefficient aphid clones in transmitting PVY strains :

To determine the relative efficiency of three forms of two aphid species (selected representative efficient and inefficient vector clones) were given the usual treatments. The observations on their ability to transmit PVY strains are recorded in Table 5. It is clear that the late stage nymphs were slightly superior though insignificantly than apterous adults as transmitters over their alatae for both the strains of PVY.

TABLE 1

Influence of fasting on aphid transmission of PVY strains by different clones of *Aphis gossypii* and *Myzus persicae.*

	% Transmission					
	PVY²			PVY⁴		
A. gossypii	0 hr	1 hr	2 hrs	0 hr	1 hr	2 hrs
H. V. I.	10	20	30	0	20	25
H. V. II.	0	10	15	0	10	20
H. V. III.	10	25	40	20	30	60
H. V. IV.	30	20	40	10	30	50
H. V. V.	10	20	25	0	20	30
M. persicae						
H. V. I	10	20	30	15	20	40
H. V. II.	10	20	25	10	30	30
H. V. III.	20	40	50	30	50	60
H. V. IV.	10	15	30	10	30	40
H. V. V.	10	20	30	15	20	30
H. V. VI.	10	20	20	15	30	30
H. V. VII.	15	20	30	15	25	40
H. V. VIII.	10	20	20	15	30	30
H. V. IX.	15	20	30	20	30	35
H. V. X.	20	25	40	25	35	50
H. V. X.	20	25	40	25	35	50
H. V. XI.	5	15	30	10	20	35
H. V. XII.	3	10	10	5	15	15
H. V. XIII.	10	20	40	20	30	55

TABLE 1

Influence of fasting on aphid transmission of PVY strains by different clones of *Aphis gossypii* and *Myzus persicae*.

	% Transmission					
	PVY[2]			PVY[4]		
A. gossypii	0 hr	1 hr	2 hrs	0 hr	1 hr	2 hrs
H. V. I.	10	20	30	0	20	25
H. V. II.	0	10	15	0	10	20
H. V. III.	10	25	40	20	30	60
H. V. IV.	30	20	40	10	30	50
H. V. V.	10	20	25	0	20	30
M. persicae						
H. V. I	10	20	30	15	20	40
H. V. II.	10	20	25	10	30	30
H. V. III.	20	40	50	30	50	60
H. V. IV.	10	15	30	10	30	40
H. V. V.	10	20	30	15	20	30
H. V. VI.	10	20	20	15	30	30
H. V. VII.	15	20	30	15	25	40
H. V. VIII.	10	20	20	15	30	30
H. V. IX.	15	20	30	20	30	35
H. V. X.	20	25	40	25	35	50
H. V. X.	20	25	40	25	35	50
H. V. XI.	5	15	30	10	20	35
H. V. XII.	3	10	10	5	15	15
H. V. XIII.	10	20	40	20	30	55

Table 2

Interaction between virus strains, clones pre-acquisition fasting and transmission feeding periods.

		% Transmission			
		PVY[2]		PVY[4]	
M. persicae		1 min[b]	5 min	1 min	5 min
	0 hr[a]	10[c]	20	20	30
H. V. III**	1 hr	30	40	45	50
	2 hr	40	50	50	60
	0 hr	10	20	15	25
H. V. X**	1 hr	20	25	30	40
	2 hr	30	40	40	50
	0 hr	5	10	10	20
H. V. VI*	1 hr	5	20	24	25
	2 hr	10	20	20	30
	0 hr	0	3	5	10
H. V. XII*	1 hr	5	5	10	20
	2 hr	10	10	10	20
A. gossypii					
	0 hr	0	5	0	5
H. V. II*	1 hr	10	10	10	10
	2 hr	10	15	15	20
	0 hr	5	15	10	20
H. V. III**	1 hr	25	30	30	40
	2 hr	30	40	40	60

* Inefficient colnes,
** Efficient,

a = fasting,
b = acq. feeding,
c = % (avg.) transmission.

TABLE 4

Effect of transmission feeding periods for PVY transmission by different clones*.

M. persicae clones	PVY[2] (% tramission)						PVY[4] (% transmission)					
	15 min	30 min	1 hr	2 hrs	4 hrs	24 hrs	15 min	30 min	1 hr	2 hrs	4 hrs	24 hrs
H. V. I.	30	30	25	25	20	30	35	40	30	35	40	45
H. V. II.	20	25	20	15	15	25	25	30	30	30	30	30
H. V. III.	45	50	50	45	45	55	50	60	60	60	60	65
H. V. IV.	30	30	30	25	15	30	40	40	35	40	40	40
H. V. V.	25	25	20	20	20	25	30	30	30	30	30	30
H. V. VI.	20	20	15	10	10	20	25	30	30	30	30	35
H. V. VII.	25	20	15	15	15	25	30	40	35	40	40	45
H. V. VIII.	15	20	10	10	10	20	25	30	30	30	30	30
H. V. IX.	20	20	15	10	10	20	25	35	35	30	35	35
H. V. X	30	40	30	35	40	45	40	50	50	50	50	50
H. V. XI.	20	20	20	15	20	20	30	35	30	35	35	35
H. V. XII.	10	10	5	5	10	10	10	15	15	15	15	10
H. V. XIII.	30	40	30	35	45	50	40	55	50	55	55	60
A. gossypii clones												
H. V. I.	20	30	30	25	25	30	15	20	20	25	25	25
H. V. II.	10	15	15	15	20	20	15	20	20	20	20	20
H. V. III	35	40	40	40	45	45	45	60	60	65	65	65
H. V. IV.	30	40	40	40	45	45	40	50	50	50	50	50
H. V. V.	10	20	20	20	20	25	25	30	30	30	35	35

* Fasting : 2 hrs. and Acquisition feeding : 5 min.

TABLE 5

Comparative efficiency of different stages of aphid clones in transmitting PVY strains.

	PVY^2			PVY^4		
	No. of plants infected by each stage out of 20			No. of plants infected by each stage out of 20		
M. persicae clones	Nymphs	Apterae	Alatae	Nymphs	Apterae	Alatae
H. V. II.	12	11	5	14	12	6
H. V. VI.	6	6	3	7	8	4
H. V. X.	10	10	4	12	11	5
H. V. XII.	5	4	3	6	5	4
Total	33	31	15	39	36	19
A. gossypii clones						
H. V. II.	8	6	2	8	6	3
H. V. III.	12	10	5	11	12	5
Total	20	16	7	19	18	8

Treatments : Fasting 2 hrs; Acquisition 5 min. and Transmission feeding 30 min.

DISCUSSION

The above mentioned results clearly suggest that differences in the pre-acquisition fasting, aphid feeding periods and virus strains do not alter the relative efficiency of an aphid vector clone. The infections produced are local and independent for each aphid individual/species/clone (Watson, 1936) and the increased transmission is only an increase in probability of transmission due to one or other factor (Bhargava, 1951; Nariani & Sastry, 1962). Further, the fall in PVY transmission due to prolonged acquisition access beyond 5 min is in agreement with the hypothesis of inhibitor (Saliva) production in aphids (Watson and Roberts, 1939) and as also supported by Day and Irzykiewicz, 1954; Bhargava, 1951; Sylvester, 1964; Nariani & Sastry, 1962; Nagaich, *et al.* 1970; Khurana, *et al.* 1973 and Singh, 1977. No difference obtained with the increase in transmission feeding periods can be explained on the ground that most of the viruliferous aphids caused infection in the initial duration of 15-30 min.

Although variable conditions of starvation, acquisition and the virus strain had some influence on the vectorial ability of an inefficient clone, such variations were either parallel or greater in the case of efficient clones. Therefore, such variations in different clones of two species under report can be attributed to a hereditary character as also suggested by previous workers (Simons, 1958, Sohi and Swenson, 1964; Upreti and Nagaich, 1971; Khurana, *et al.*, 1976; Singh 1977).

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The Aphids : 229-233

APHIDS OF AGRICULTURAL IMPORTANCE AND THEIR NATURAL ENEMIES AT JULLUNDUR (PUNJAB)*

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ABSTRACT

Results of an extensive survey for aphids and their natural enemies around Jullundur, Punjab are presented. The species of aphids feeding on economic plants and weeds are reported. The natural enemies include 7 species of parasites and 16 species of predators. Life history and seasonal occurrence of seven species of predators have been studied. Feeding capacity of *Scaeva albomaculata* Macq., during larval period, varied between 25 and 35 aphids per day.

INTRODUCTION

Aphids draw attention of all engaged in cultivation due to their occurrence in large numbers on crops. Aphids, apart from causing direct damage by feeding are known to act as vectors of virus diseases. These have wide host range including both economic crop plants and certain weeds. The author, therefore, surveyed the aphid fauna around Jullundur, Punjab and their natural enemies.

APHIDS OF JULLUNDUR

Acyrthosiphon pisum (Harris) was found in pure colonies on *Trifolium alexandrinum* and *Trigonella foenum-graecum*, *Cicer arietinum*, and *Pisum sativum*. On *C. arietinum*, heavy incidence was noticed in mid-March and also mid-October.

Aphis gossypii Glover is a widely distributed species and was found feeding on *Cestrum nocturnum*, *Cucurbita pepo*, *Gossypium* spp., *Luffa acutangula*, *Psidium guajava* and *Solanum melongena*. This aphid often occurred in mixed colonies.

Lipaphis erysimi (Kaltenbach) is a serious pest of mustard and radish around Jullundur. Host-plants : *Brassica nigra*, *B. oleracea* var. *capitata* and *B. oleracea* var. *botrytis*.

* Work done by the author at Commonwealth Institute of Biological Control, Sub-station Jullundur under a US PL. 480 Project "Survey for Natural enemies of Aphids in India".

Myzus persicae (Sulzer) is another widely distributed species and was found in mixed colonies with *Hyadaphis coriandri* Das on *Coriandrum sativum.* It was also found feeding on *Beta vulgavis*, *Daucus carota*, *Ipomea* sp., *Solanum tuberosum*, *Solanum melongena*, *Solanum lycopersicum*, *Rumex dentatus*, *Cyphomandra betaceae* and *Nicotiana tabacum.*

Other aphids found around Jullundur were *Aphis craccivora* Koch., on *Cicer arietinum;* *Aphis rhoicola* H. R. L. on *Rumex dentatus;* *Brevicoryne brassicae* (Linnaeus) on brassicas; *Hayhurstia atriplices* L., on *Chenopodium* sp., and *Macrosiphum sanborni* on *Chrysanthemum* sp.

PARASITES

The parasites reared from different aphid hosts during the period of survey are as follows :

Name of the parasite	Name of host aphid	Name of plant host of the aphid
1. *Aphelinus* sp.	*Aphis gossypii*	*Gossypium* sp.
2. *Aphelinus semiflavus*	*Myzus persicae*	*Solanum* spp. Brassicas.
3. *Aphidius smithi* Sharma and Subba Rao	*Acyrthosiphon pisum*	*Pisum sativum*
4. *Aphidius* sp.	*Aphis grosypii*	*Solanum melongena*
5. *Binodoxys indicus* Subba Rao and Sharma	*Myzus persicae*	*Cyphomandra betaceae*
	Macrosiphum sanborni	*Chrysanthamum* sp.
	Aphis craccivora	*Cicer arietinum*
6. *Diaeretiella rapae* (M' Intosh)	*Brevicoryne brassicae*	Brasiccas
	Hayhurstia atriplices	*Chenopodium* sp.
	Lipaphis erysimi	Brassicas
7. *Lysiphlebus* sp. (probably n. sp)	*Aphis gossypii*	*Gossipium* spp.

PREDATORS

Predators of aphids are knowa to play an important role in reducing the aphid population. However, around Jullundur no specificity of these predators to particular aphid was observed. The following aphid predators were collected.

Coccinellidae (Coleoptera) :

1. *Coccinella septumpunctata* Linn. : This coccinellid was the most common predator found associated with *A. gossypii*, *A. craccivora* and *L. erysimi*. It was abundant in October and November, tending to decline by January. The life-history was studied during October-December. The eggs hatched in 4-5 days in October and 5-7 days during November-December. The first, second and third instars lasted 3-9, 2-4 and 5-8 days respectively and pupal period 4-6 days.

2. *Menochilus sexmaculatus* F. : This was the most common pradator found feeding on *A. gossypii*, *A. craccivora*, *L. erysimi*, *B. brassicae* and *M. persicae*. The populations remained high upto the second week of December and declined in January. Eggs hatched in 4-5 days in October. Larval and pupal periods ranged from 9-14 and 4-12 days respectively during November and December.

Syrphidae (Diptera) :

3. *Melanostoma orientale* Wied : Very few specimens were collected. The larvae fed on *L. erysimi*.

4. *Paragus tibialis* Fall : This predator was found sometimes associated with *A. gossypii* on *Gossipium* sp.

5. *Scaeva albomaculata* Macq. : Larvae of this syrphid fed on *L. erysimi* and *M. persicae*. Copulation lasted 125-290 minutes (mean 200 minutes; mean of 10 pairs). The eggs hatched on the fifth and sixth day. The first, second, third instars and pupal period lasted about 5.2, 3.7, 7.8 and 14.5 days respectively during December-January and 3.5, 4.6, 6.3 and 11 days during January-February.

The number of *L. erysimi* consumed by *S. albomaculata* during each instar is given in Table 1.

TABLE 1

Feeding capacity of larvae of *S. albomaculata*.

Stage	Number of *L. erysimi* consumed per day	
	Mean	Range
1st instar	3	1-5
2nd instar	5	1-8
3rd instar	24	18-28
Total consumption during larval period	32	25-35

6. *Sphaerophoria indiana* Bigot: This syrphid fed on *L. erysimi* on mustard and occasionally on *M. persicae* on *N. tabacum*. The population was moderate in December but tended to increase by January. The female laid 37-45 eggs during its life time. The eggs hatched in 4-6 days in November. The larval period lasted 16-43 days or even more. This species hibernates in larval stage in December-January. The pupal period was 16-18 days. Males lived for 3-12 days in November-December while females lived for 26 days when fed on aqueous solution of honey.

7. *Syrphus balteatus*: It is one of the most common predators feeding on many aphid species found around Jullundur.

8. *Syrphus confrater* Wied.: Larvae of *S. confrater* were found feeding on *A. gossypii* and *A. craccivora.*

9. *Xanthogramma scutellare* Fab.: Although it is a very common and important predator feeding on several aphid species at Jullundur, the population remained low apparently due to competition with other predator species, particularly with other species of syrphids. The larval period lasted for 13-14 days in November but one batch of larvae pupated within 8-9 days. The pupal period ranged from 15-17 days but in one batch it lasted about 10 days. The pupal period lasted 7-9 days in October, 13-17 days in November, 22-23 days in December and 20-21 days during January.

10. *Lasiopticus pyrastri* L.: Larvae of this syrphid were found feeding on several species of aphids including those on Brassicas during October. Its activity was very pronounced in mustard fields where severe infestation of *L. erysimi* was noticed.

Chamaemyiidae (Diptera):

11. *Leucopis minae* Tanas: It feeds on *Aphis gosspyii, A. craccivora, L. erysimi* and *M. persicae.* This predator was reared during January, February and May to December. The life history studied in November showed the pre-oviposition period to be 3-6 days, egg period 2-3 days, larval and pupal period 8-9 days and 17-18 days respectively.

Chrysopidae (Neuroptera):

12. *Chrysopa* sp. (*carnea* group): Larvae of this species were predaceous on *Aphis gossypii* on *Gossypium* sp. The eggs were laid 20 days

after mating. Eggs hatched in 8-9 days. The first, second and third instars lasted 8-13, 13 and 11-24 days respectively during October-January. The pupal period lasted 12 days during October-November. This predator hibernates in the adult stage.

Anystidae (Acarina):

13. *Anystis* sp. Small numbers of this predaceous mite fed on *A. gossypii.*

Other predators observed at Jullundur are the syrphids, *Eristalis tenax* L., *Eristalis quinquestriatus* Fab. and *Eristalis paris* Bigot. These were collected on wing in mustard fields and perhaps fed on *L. erysimi.*

A Bethylid, *Parasierola* sp., was occasionally reared from field collected syrphid pupae during October.

The important aspect to be noticed from the above account is that around Jullundur the number of parasite species were few and were less abundant. But predators were available in large numbers. In spite of high predator populations, the aphids expressed large populations during the year under survey. There is however, a need for detailed survey for the natural enemies of aphids to record additional natural enemies which may be useful in controlling the pest.

ACKNOWLEDGMENTS

The author is thankful to Dr. V. P. Rao, the then Entomologist-in-charge, Commonwealth Institute of Biological Control, Indian Station, Bangalore for providing necessary facilities and encouragement during the investigation. Thanks are also due to the Chief Identification and Parasite Introduction Research Branch, Entomology Research Division, U. S. Department of Agriculture, Beltsville, Maryland, U. S. A., and Director, Commonwealth Institute of Entomology, London for identification of the aphids and their natural enemies.

The Aphids : 234.237

PREDATION BY *COCCINELLA SEPTEMPUNCTATA* LINN., AND *MENOCHILUS SEXMACULATA* FAB., ON FIVE SPECIES OF APHIDS

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ABSTRACT

Studies on the extent of predation by *C. septempunctata* and *M. sexmaculata* on five different species of aphids viz., *L. erysimi*, *B. brassicae*, *A. craccivora*. *M. pisi* and *A. gossypii* shows that *L. erysimi* is consumed in largest numbers by both the species of beetles, while *M. pisi* and *A. craccivora* are consumed almost equally and *A. gossypii* is preyed upon in least numbers.

INTRODUCTION

The lady-birds or coccinellids (Coccinellidae : Coleoptera) form a very important group of insects, as they are mostly predaceous, and thus help to keep crop pests such as plant-lice (aphids), scales (coccids) and mealywings (aleurodids) in check. A few species of these beetles are even reported to feed on lepidopterous larvae. The lady-birds are predaceous in both the larval and adult stages with few exceptions. There is, however, one set of coccinellids known as *Epilachna* beetles that are vegetable feeders and these occur in large numbers as pests on various crops.

The predatory coccinellids have played an important role in the development of biological control. The introduction of *Rodolia cardinalis* Mulsant from Australia into California against the Cottony cushion scale, *Icerya purchasi* Maskell was the first dramatic case of biological control.

Work on predation of coccinellids on aphids is rather scattered and fragementary. Clausen (1915) determined feeding rate for eight species of coccinellids and found that the larvae of each species consumed 11-25 aphids daily. Schilder and Schilder (1928) reviewed the type of prey consumed by different coccinellids. Hagen (1962) gave on account of the biology and ecology of predaceous coccinellids. Hodek (1962) stated that the aphid feeding coccinellids are not so polyphagous as was presumed earlier and that they have specialized food requirements depending upon the biochemical composition of aphids. Smith (1965) also observed that coccinellids show preference for certain species of aphids but may consume others when better food is not available.

Studies were initiated to find out the extent of predation by two commonly occurring species of coccinellids viz., *Coccinella septempunctata* Linnaeus and *Menochilus sexmaculata* (Fabricius) on five different species of aphids viz., the mustard aphid, *Lipaphis erysimi* (Kaltenbach); cabbage aphid, *Brevicoryne brassicae* Linnaeus; bean aphid *Aphis craccivora* Koch; pea aphid, *Macrosiphum pisi* Kaltenbach and cotton and brinjal aphid, *Aphis gossypii* Glover.

MATERIALS AND METHODS

The adults of both the species of coccinellids viz., *C. septempunctata* and *M. sexmaculata* were collected from the field and were kept under laboratory conditions for 6-8 hours, without any food. One adult was kept in each jar and was provided with fifty freshly collected adult apterous aphid specimens. Counts of aphids eaten during a 24 hour period were made in each case and fifty fresh new aphids were reintroduced, Observations on the feeding of aphids were recorded for three days in case of each aphid species.

RESULTS

The data on the mean number of aphids eaten by these species is presented in Tables 1 and 2. The mustard aphid, *L. erysimi* was consumed in the largest number by both the species of coccinellids while, *M. pisi* and *A. craccivora* were consumed almost equally. *A. gossypii* was consumed in the least number by both the species of coccinellids. It was also observed that these coccinellids occur in the same habitat feeding upon the same species of aphid in the field. It is interesting to note that the adults do not perceive prey until contact.

It is evident from tables 1 and 2 that there is great difference in the number of aphids of different species consumed by adults of *C. septempunctata* and *M. sexmaculata.*

TABLE 1

Predation of *Coccinella septempunctata* Linn., on different species of aphids.

Species of aphid	Mean No. of aphids consumed during 24 hours
Lipaphis erysimi Kalt.	36.6
Brevicoryne brassicae L.	31.6
Aphis craccivora Koch.	12.0
Macrosiphum pisi Kalt.	13.3
Aphis gossypii Glover.	10.6

TABLE 2

Predation of *Menochilus sexmaculata* Fab., on different species of aphids.

Species of aphid	Mean number of aphids taken during 24 hours
Lipaphis erysimi Kalt.	20.3
Brevicoryne brassicae L.	17.6
Aphis craccivora Koch.	12.6
Macrosiphum pisi Kalt.	14.3
Aphis gossypii Glover	8.0

ACKNOWLEDGMENTS

The author wishes to express sincere thanks to Dr. M. G. Jotwani, Head of the Entomology Division, IARI, New Delhi-12 for providing necessary facilities. Thanks are also due to Dr. M. G. Ramdas Menon, former Senior Systematic Entomologist, for identification of aphids, and to Dr. B. R. Subba Rao for guidance.

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The Aphids : 238-244

AN ACCOUNT OF SYRPHID (DIPTERA : SYRPHIDÆ) PREDATORS OF APHIDS AVAILABLE IN DARJEELING DISTRICT OF WEST BENGAL AND SIKKIM

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INTRODUCTION

Syrphids form an important component of predatory complex of aphids. It is rare to find an aphid colony on a plant without a syrphid larva. Knowledge about the syrphid predators of aphids in India has accumulated chiefly through the works of Bhatia and Shaffi (1932), Cherian (1934), Rahman (1940) and Rao (1969). Among these workers it was Rao (1969) who for the first time reported 8 syrphid species predaceous on aphids in Kalimpong of Darjeeling district, West Bengal.

The present work reports our investigations on the syrphid predators of Kalimpong and Sikkim.

MATERIALS AND METHODS

1. Syrphid flies were obtained by rearing eggs and/or maggots available on aphids during different periods of a year.
2. Adult syrphid flies were kept in dry condition and identified through the courtesy of Zoological Survey of India, Calcutta.
3. Aphid hosts were collected in 70% alcohol in the field and subjected to usual processing and mounting procedure for microscpical study.
4. Host range and seasonal occurrence of the syrphid predators were determined from the collection data of the aphid with which eggs and/or maggots of the flies were found.

5. Studies on life-history and voracity of *Sphaerophoria scripta* were conducted under room conditions at Kalimpong (*c* 1280 m). For this purpose newly laid eggs were collected from the field along with aphid infested plant parts and kept in a pair of petri dishes. Observations in respect of developmental period and voracity were made at an interval of every 24 hours.

6. Syrphid larvae were provided with fresh aphids every 24 hours till pupation.

OBSERVATIONS

1. *Allograpta javana* (Wiedmann)

Hosts: *Macrosiphum rosae* (L.) and *M. rosaeiformis* Das ex. *Rosa* sp.

Locality: Kalimpong.

Collection period: April—May.

2. *Betasyrphus serarius* (Wiedmann)

Hosts: *Macrosiphum rosae* (L.) ex. *Rosa* sp.; *Aphis spiraecola* Patch ex. *Bidens pilosa* and *Lipaphis erysimi* (Kaltenbach) ex. *Brassica oleracea* var. *capitata.*

Locality: Kalimpong.

Collection period: March—April.

3. *Dideopsis aegrota* (Fabricius)

Hosts: *Aphis spiraecola* Patch ex. *Artemisia vulgaris* and *Bidens pilosa.*

Locality: Kalimpong.

Collection period: July—October.

4. *Epistrophe griseocincta* (Brunetti)

Hosts: *Rhopalosiphum maidis* (Fitch) ex. *Hordeum vulgare.*

Localily: Sikkim.

Collection period: November.

5. *Episyrphus balteatus* (De Geer)

Hosts: *Aphis gossypii* Glover and *Myzus persicae* (Sulzer) ex. *Cyphomendra betaceae* and *Cucumis sativus; Melanaphis sacchari* (Zehntner) ex. *Zea mays; Myzus persicae* (Sulzer)* ex. *Solanum tuberosum.*

Localities: Kalimpong, Sikkim*.

Collection period: Throughout the year.

6. *Ischiodon scutellaris* (Fabricius)
Hosts : *Acyrthosiphon pisum* (Harris) ex. *Pisum sativum.*
Locality : Kalimpong.
Collection period : March—May and November—December.

7. *Melanostoma orientale* (Wiedmann)
Hosts : *Melanaphis sacchari* (Zehntner) ex. *Saccharum officinarum* and *Rhopalosiphum maidis* (Fitch) ex. *Hordeum vulgare.*
Locality : Sikkim.
Collection period—December.

8. *Paragus tibialis* (Fallen)
Hosts : *Aphis spiraecola* Patch ex. *Bidens pilosa.*
Locality : Kalimpong.
Collection period : August—October.

9. *Paragus yerburiensis* Stuckenberg.
Hosts : *Aphis spiraecola* Patch ex. *Bidens pilosa.*
Locality : Kalimpong.
Collection period : January—March and August—December.

10. *Metasyrphus confrater* (Wiedmann)
Hosts : *Aphis gossypii* Glover and *A. spiraecola* Patch ex. *Bidens pilosa.*
Locality : Kalimpong.
Collection period : Janaury—June and October—December.

11. *Sphaerophoria scripta* (Linnaeus)
Hosts : *Aphis craccivora* Koch ex. *Dolichos lablab; A. gossypii* Glover ex. *Capsicum annum; Brachycaudus helichrysi* (Kaltenbach) ex. *Ageratum conyzoides; Macrosiphum rosae* (L.) and *M. rosaeiformis* Das ex. *Rosa* sp.; *Mollitrichosiphum* (*Metatrichosiphum*) *nandii* Basu ex. *Alnus nepalensis.*
Locality : Kalimpong.
Collection period : April—May.

12. *Xanthogramma scutellare*
Hosts : *Aphis craccivora* Koch ex. not known; *A. gossypii* Glover ex. *Solanum melongena; A. spiraecola* Patch ex. not known; *Brevicoryne brassicae* (L.) ex. *Brassica caulotrapa; Lipaphis erysimi* (Kalt.) ex. *B. caulotrapa; Myzus persicae* (Sulzer) ex. *Solanum melongena.*

Locality : Kalimpong.
Collection period : Throughout the year.

Voracity and developmental period of *Sphaerophoria scripta* (L.).

At Kalimpong eggs of this fly were collected from the colonies of *Macrosiphum rosae* and *M. rosaeiformis* infesting apical shoots of rose plants. The larval period of the syrphid species lasted 13-15 days. A first day larva consumed 3-6 aphids in 24 hours. The rate of consumption increased till seventh day when a larva could devour 54-56 aphids per day. Thereafter the rate declined during the rest of the larval period. During the entire larval period a larva consumed about 321-419 aphids. Total developmental period of the syrphid has been found to vary between 32 and 36 days comprising incubation period : 5-6 days, larval period : 13-15 days and pupal period : 14-15 days when the mean temperature was between 14°C and 17°C and mean relative humidity varied between 84.5 and 87% (Fig. 2).

DISCUSSION

In nature the aphids are mostly known to be predated upon by syrphids. In India about 32 syrphid species have been reported to predate upon a number of aphid species (Bhatia and Shaffi 1932, Cherian 1934, Rahman 1940, Rattanlal and Haque 1955, Anand *et al.* 1967, Rao 1969, Saxena *et al.* 1970, Zaka ur—Rab 1972, Vadivelu *et al.* 1975, Raychaudhuri *et al.* 1978). Among these syrphid species 8 were so far known from the Darjeeling district of West Bengal (Rao, 1969) and none from Sikkim as predator of aphids. Through the present work 4 more species of syrphid predators are reported. *Betasyrphus serarius*, *Episyrphus balteatus*, *Melanostoma orientale* and *Xanthogramma scutellare* appear to be polyphagous in the area of the present study (Fig. 1). Their polyphagous nature is also known from other parts of the country (Rao 1969, Rahman 1940, Bhatia and Shaffi 1932). Notwithstanding above, *Melanaphis sacchari* and *Rhopalosiphum maidis* are reported as new hosts for *Melanostoma orientale* at least under Indian conditions. Some of the predatory syrphids e. g., *Allograpta javana*, *Ischiodon scutellaris*, *Paragus yerburiensis* and *Metasyrphus confrater* apparently appear to be monophagous in the area of investigation (Fig. 1) but Rao (1969), Rahman (1940), Anand *et al.* (1967) and Zaka ur-Rab (1972) reported some other aphid species as the host of these predators from other parts of India.

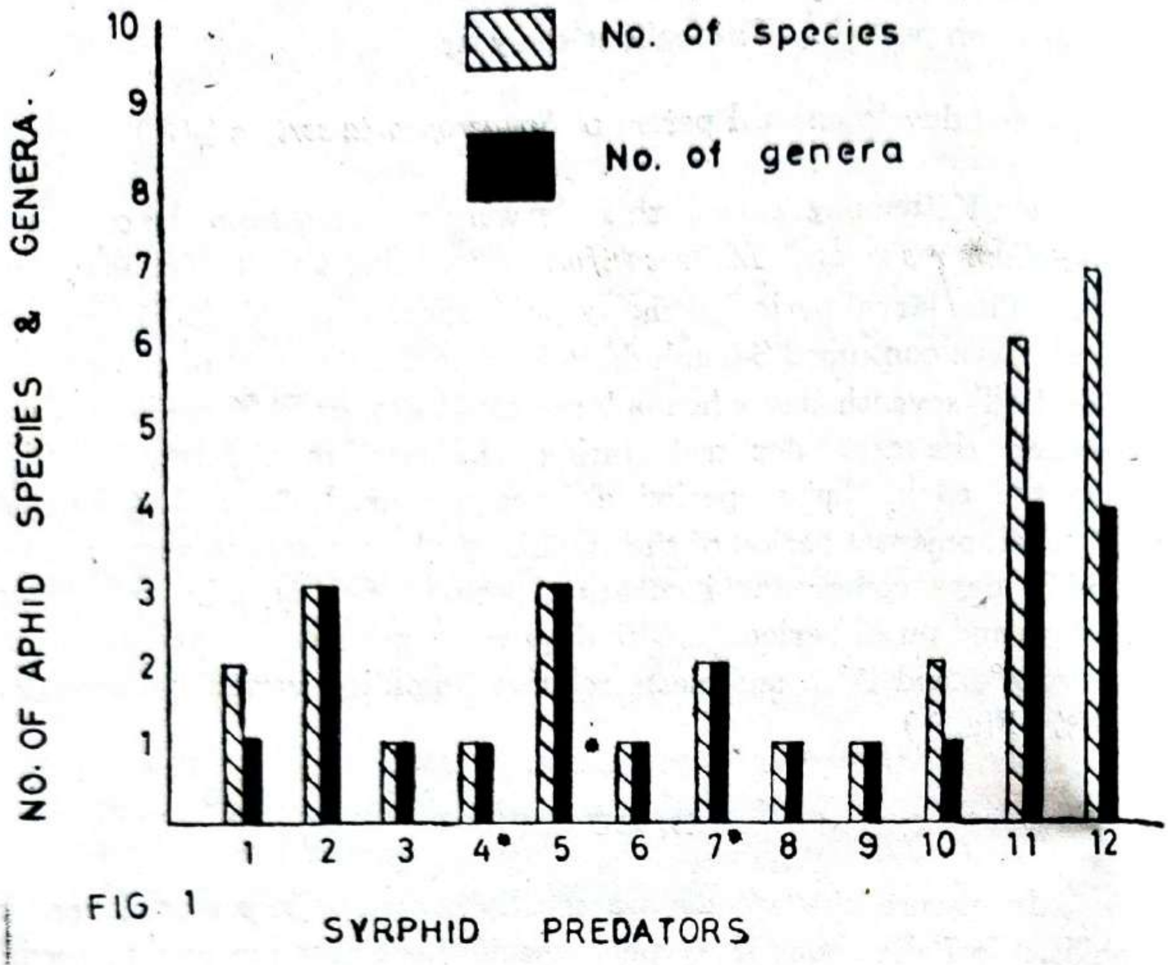

FIG. 1

HOST RANGE OF SYRPHID PREDATORS FOUND IN KALIMPONG, DARJEELING DISTRICT OF WEST BENGAL AND SIKKIM.*

From the collection data it is observed that the subfamily Aphidinae is most exposed to predation by syrphids. This is because of the abundance of the members of this aphid subfamily in nature. Genus-wise break-up of the subfamily reveals that *Aphis* and *Macrosiphum* are mostly predated upon by these syrphids. The reason attributed to the phenomenon of predation on the subfamily Aphidinae holds good for the genera *Aphis* and *Macrosiphum.*

The collection data also bring out the fact that predation by syrphids is more pronounced during the period November to February. This period also coincides with the period of abundance of aphid species in nature. This may be looked upon as a case of natural check of the aphid population. Thus it appears that there exists a close relationship between the abundance of aphids and the number of syrphid larvae and thereby species. This finding also corroborates with the views of Bhatia and Shaffi (1932).

From tha observations on the developmental period of *Sphaerophoria scripta* it was found that the insect completes its life history in about 32-36 days, the incubation period being 5-6 days, the larval period 13-15 days and the pupal period 14-15 days in temperature varying between 14°C and 17°C and relative humidity 84.5 — 87% at Kalimpong. No

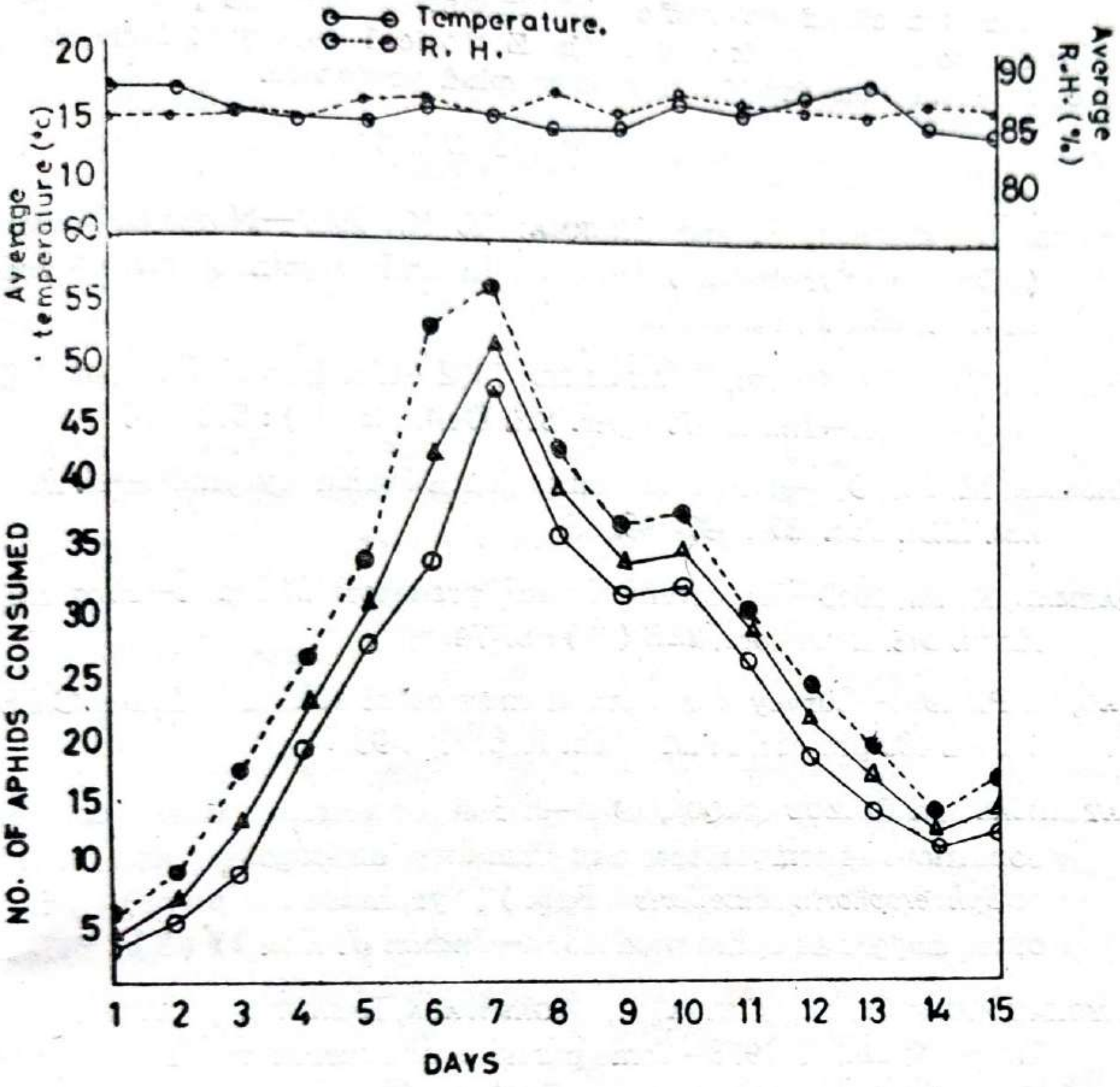

Fig. 2 VORACITY OF LARVAE OF SPHAEROPHORIA SCRIPTA L. ON MACROSIPHUM. ROSAE (L.) AND M. ROSAEIFORMIS DAS IN KALIMPONG, DARJEELING DISTRICT OF WEST BENGAL.

O Minimum. Δ Mean. ● Maximum.

published record is available on the life history of this particular predator. Through personal communication from another colleague of this laboratory it appears that in the neighbourhood of Calcutta the insect completes its life-history in about 14-17 days when temperature varied between 28.3°C and 34°C and relative humidity ranged between 60% and 73%.

As to the voracity of this syrphid, the first day larva consumed 3—6 aphids while a seventh day larva consumed 54—56 aphids (Fig. 2).

ACKNOWLEDGMENTS

Thanks are due to Indian Council of Agricultural Research, New Delhi and Council of Scientific and Industrial Research, New Delhi for partly financing the work and to the Zoological Survey of India, Calcutta for commenting on the identity of syrphid predators.

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The Aphids : 245-250

TRIOXYS (BINODOXYS) INDICUS SUBBA RAO & SHARMA AS A POSSIBLE BIOLOGICAL AGENT IN THE CONTROL OF APHIS CRACCIVORA KOCH.

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INTRODUCTION

Environmental pollution by chemicals and the development of insecticide resistance in pests of agricultural and public health importance has posed a constant threat to mankind and it has become necessary to evolve control measures which may be selective in action and relatively harmless to non-target organisms. Biological control of the pest population is much more effective, selective and safe for humanity.

Historical development—

The discovery of agriculture during Neolithic times (10,000 B.C.) and its development put human kind into very direct competition with insects for food. Just as early man observed birds eating insects and snakes eating rodents he must also have noted the proclivity of certain wild felines towards a diet of mice and rats like those which infested his stores of grain and other foods. And so the domestication of the house cat may well have been encouraged and may be considered as a very early attempt at biological control. It was in 1668, when Francesco Redi first observed parasitism in an aphid. Recent publications on biological control indicate the tremendous interest in the subject with the result that various views on theories and practices of biological control have been put forward (Johansen, 1957; Rao *et al*., 1971; Huffaker, 1971; DeBach, 1974; Huffaker & Messenger, 1976; Coppel & Mertins, 1977).

Biological control in its broad sense may be defined as the use or encouragement by man of living organisms or their products for the population reduction of insect pests. Parasitic insects are the most important parameter for biological control of pests (DeBach, 1974) because of their higher biotic potential rates of reproduction (Odum, 1971).

The search for efficient beneficial organisms, for use in biological insect pest suppression requires that we have some idea beforehand of what we are seeking for. It is generally recognized that there is no sure way of predicting beforehand the success or failure of a species in giving adequate pest suppression. The answer to this question can be determined with certainity only empirically. However, whether we are looking for introducing new or exotic natural enemies, or analysing the indigenous ones, it is essential to know the characteristics which tend to make a species display an efficient regulatory relationship with a pest. Some of these characteristics or attributes are intuitively discernable in the light of the ideas of population dynamics and natural control, and some of them have been recognized only through experience in previous biological control programmes. Many of the attributes are closely interrelated and difficult to separate from each other.

Also for a successful biological pest control programme it is necessary to determine if the pest is a real pest species or a man-made pest generated by the use of pesticides or some other upsetting agency. In the case of man-made pest, the natural enemies of the pests are usually already present, but their effectiveness has been destroyed or impaired by adverse human activities. There may be no need to establish new suppressive agents if the beneficial effect of those already present can be restored or improved through the conservative practices and evaluation of their biological characteristics.

Aphis craccivora is cosmopolitan in distribution. It feeds on a wide range of field crops, vegetables and some fruits. ***Trioxys (Binodoxys) indicus*** Subba Rao & Sharma an aphidiid wasp, in addition to an unidentified aphilinid wasp was found to parasitize ***A. craccivora*** locally in pigeon pea growing areas.

To assess the usefulness of ***T. indicus*** as a bioagent for the control of ***A. craccivora*** the study of various aspects of the biology of this parasitoid has been made.

MATERIALS AND METHODS

A. cruccivora was cultured in the laboratory on the cuttings of ***Cajanus cajan***, a single cutting containing 4-6 leaves, the stem of which was placed in 60 ml glass vial containing water. Cuttings were replaced on every third day. Old cuttings with aphids were placed on the new cuttings which helped in their transference to the new cuttings. After 6 hrs those which still did not move to the new cuttings were transferred carefully with fine camel hair brush. The vials with cuttings were kept separately in jars (12" × 3") whose mouths were stoppered with pieces of muslin cloth secured in position with the help of rubber bands. For the culture of *T. indicus* mated female parasitoids were introduced in such jars. The parasitized aphids when mummified were separated and allowed to develop singly in tubes. For experimental studies this culture was used. To study the different desired attributes of the parasitoid different experimental set up were designed (see Sinha & Singh, 1979a, 1979b, 1979c, 1979d).

OBSERVATIONS AND DISCUSSION

(1) *Host searching capacity and dispersal of the parasitoid* : The searching capacity of a parasitoid is a composite of its physical, chemical, psychological and mechanical qualities which is achieved through several phases, viz., ecological selection, i. e., host-habitat finding; psychological selection, i. e., host acceptance and finally physiological selection, i. e., host suitability. A parasitoid beneficial as bioagent must successfully utilize the low density population of pest. *T. indicus* has been found capable of attacking 78.4% of the aphids within 15 min. of exposure period at a given host population of 25 aphids, indicating its high searching capacity, i. e., the ability to find the hosts when the host density is low. This is a more important attribute than a higher reproductive potential.

Studies made on the area of discovery of *T. indicus* revealed that it also has a high searching efficiecy at higher host densities. This behaviour enables the parasitoid to reproduce more rapidly at such densities. It has also a higher value of mutual interference (Hassell, 1971) caused by the abundance of parasitoid at relatively lower host population which helps the parasitoid in their dispersal and favours the spread of the area of interactions (Sinha & Singh, 1979b, 1979c, 1979d).

(2) *Density responsiveness behaviour of the parasitoid* : The study conducted on density responsiveness behaviour indicates that *T. indicus* has a non-random searching pattern with regard to host density, i. e., it has a density-dependent relationihip with its host (Sinha & Singh, 1979d).

(3) ***Ecological compatibility and reproductive potential of the parasitoid***: *T. indicus* and *A. craccivora* both inhabit the same ecological situations and seek similar ecological requirements. Therefore, *T. indicus* is expected to have a better ecological compatibility with the aphid. *T. indicus* has a high reproductive potential by having high fecundity and a short life cycle of 15-20 days. An individual female parasitoid parasitizes 100-150 aphids in course of 3-5 days after emergence. It helps the parasitoid to reproduce and synchronize the reproductive activity of the aphid.

A. craccivora appears on *C. cajan* during the 2nd week of December and continues till the first week of April. The maximum infestation observed was during the month of February. Field collections of the aphids revealed that *T. inidcus* appears in the field near about the 3rd week of December, parasitizing 9.4% of the aphid population. However, the peak of parasitism, i. e., 64.6% is reached during the middle of February resulting in the suppression of population of *A. craccivora*. It has further been observed that the sex-ratio of *T. indicus* favours the female sex. This behaviour of reproduction in nature helps in the successful establishment of the parasitoid because it is the female parasitoid which produces the desired level of mortality (Sinha & Singh, 1979a).

(4) *Host-specificity of the parasitoid*: Another attribute which contributes to the success of a parasitoid in the control of their host, is the host-specificity. A parasitoid which is monophagous or slightly oligophagous has a high degree of biological adaptation to the host and also has a greater degree of direct and rapid responsiveness to density changes in the population of the target host (DeBach, 1974). *T. indicus* is not strictly a host specific parasitoid as it is also reported to parasitize other species of aphids, viz., *A. gossypii* Glover (Subba Rao & Sharma, 1962), *A. nerii* Fonsc. (Shujauddin, 1673) etc. *A. gossypii* is another pest of of pigeon pea and it was also observed that both the species (*A. gossypii* and *A. craccivora*) either co-exist on the same leaf, or on different branches of the same plant or separately on different plants in the same field. In the laboratory, both the species were more or less equally parasitized. Information on the preference of either of the host species is lacking and needs further investigation. Subba Rao & Sharma (1962) have described the biology of this parasitoid originally on *A. gossypii*. The other aphid species is not very common in the growing areas of *C. cajan*. Also *A. nerii* is less preferred than *A. craccivora* by *T. indicus*. The above mentioned

characteristic of *T. indicus* regarding host specificity indicates that it has an oligophagous tendency. Naturally it can conveniently be applied as a biologicol control agent in the control of both *A. craccivora* and *A. gossypii* at the same time.

(5) Hyperparasitism of the parasitoid: Hyperparasitism is a negative attribute of a parasitoid. *T. indicus* is hyperparasitized 0.2-2.36% by an unidentified cynipid wasp. In nature it is very low and so insignificant.

The above studies conducted on *T. indicus* reveal that it possesses most of the desired attributes and therefore, may be used as a tool in the biological control of both *A. craccivora* and *A. gossypii*.

Perspectives in Biological control—

Recent developments in the field of insecticide utilization have clearly demonstrated that insecticides will never permanently solve the great majority of pest problems as some enthusiasts once thought of. These developments are, in fact, now bringing about ever increasing support and interest in biological control. All phases of biological control will have to expand. In the case of using parasitoids as a bioagent, the following aspects of their biology must be clearly understood.

1. Population dynamics of host and parasitoid.
2. Reproductive behaviour of the parasitoid.
3. Host selection behaviour of the parasitoid.
4. Manner and place of oviposition of the parasitoid.
5. Mechanism of fertilization, sex determination and the regulation of sex ratio.
6. Bioclimatic studies and their effect on limitation of survival of parasitoids in the introduced area.
7. Evaluation of culture technique of host and parasitoid.

ACKNOWLEDGMENT

Thanks are due to Dr. G. S. Shukla, Prof. & Head, Deptt. of Zoology, University of Gorakhpur for providing necessary research facilities and to C. S. I. R. New Delhi, for financial support.

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The Aphids : 251-258

THE BLACK APHID, *APHIS CRACCIVORA* KOCH ON PULSES IN PUNJAB

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ABSTRACT

Influence of dates of sowing and of cultivars of *Lens culinaris* and *Vigna mungo* on the incidence of *Aphis craccivora* is reported.

INTRODUCTION

In the Punjab state pulse crops are grown in about 385 thousand hectares. The major pulse crop of the state is chickpea, *Cicer arietinum* L. However lentil, *Lens culinaris* M., blackgram, *Vigna mungo* L., greengram *Vigna radiata* (L.) W. and pigeonpea, *Cajanus cajan* L., are also grown in the state and occupy about 10.0 per cent of the total area under pulses. These crops are attacked by more than 250 insect-pest species. However, among those about a dozen are the major and serious pests including the black aphid, *Aphis craccivora* Koch.

Incidence of *A. craccivora* in pulse crops has been recorded by a number of workers. Patel and Patel (1971), Waghmare and Pokharkar (1974) and Bakhetia and Sidhu (1977) while studying the host-range of the black aphid, recorded its incidence on pigeonpea, chickpea, lentil, greengram, blackgram, clusterbean, soybean, gardenpea, cowpea and lablab. A number of workers have studied the efficacy of different insecticides for the control of black aphid on various pulse crops (Sarup *et al.*, 1961; Dewan *et al.*, 1969; Kuppuswamy *et al.*, 1971; Sharma and Verma, 1972; Attri and Rattan lal, 1975; Sarup *et al.*, 1974; Das *et al*, 1975; Chopade, 1975; Visalakshi *et al.*, 1976; Bindra and Sagar, 1976; Srivastava and Singh, 1976; and Das *et al.*, 1977). Similarly, Panda and Raju (1972); Chari *et al.*, (1976) and Pal *et al.*. (1977) while screening the greengram, cowpea and blackgram material respectively, studied the intensity of the incidence of black aphid on these crops.

In the Punjab State the black aphid is a serious pest of lentil, black-gram, greengram and gram. During some years it poses a serious problem and warrants its control. Since the pulse crops in the Punjab State are grown on the land of marginal productivity, farmers are reluctant to incur any inputs to these crops including pesticides for the control of pests. It was, therefore, considered necessary to study the effect of dates of sowing on the incidence of black aphid on some cultivars of lentil having high yield potential. Similarly, field experiments were laid out to record the incidence of black aphid on some promising cultivars of lentil and to screen germplasm material of blackgram against this pest.

A. *Infuence of dates of sowing on the incidence of black aphid, A. craccivora on some promising material of lentil*

A field evperiment was laid out to study the influence of dates of sowing (D. O. S.) on the incidence of black aphid, *A. craccivora*. Four cultivars of lentil, viz., Pant 209, Pant 406, LG 112 and L 9-12 (standard) were sown on four dates of sowing— 2.11.78 (D 1). 15.11.78 (D 2), 30.11.78 (D 3) and 15.12.78 (D 4). The trial was laid out in split plot design having four replications. Tnere were 10 rows in a plot size of 6.5 × 1.8 sq. m.

Observations to record the incidence of black aphid were taken twice (3.2.79 and 3.3.79) during the crop season. For taking the observation, five plants per plot were randomly selected. Each selected plant was thoroughly tapped on a cardboard sheet duly pasted with white paper, so as to let the aphid nymphs and adults drop on to it. Population of aphid per plant was thus counted. In this way average aphid population per plant per replication was worked out. The data so collected have been statistically analysed and presented in table 1.

RESULTS AND DISCUSSION

From the data presented in table 1, it is revealed that there was no significant difference in the aphid population in between the four cultivars under test. However, dates of showing did play a significant role on the population dynamics of the pest. Population of aphid up to the first week of February was significantly high in D 1 in comparison to D 2, D 3, and D 4. D 3 and D 4 had significantly low aphid population in comparison to D2.

TABLE 1

Incidence of black aphid, ***Aphis craccivora*** Koch on some promising lentil cultivars under different dates of sowing.

Cultivar	Average aphid population per plant									
	First observation (3.2.79)					Second observation (3.3.79)				
	D 1	D 2	D 3	D 4	Mean	D 1	D 2	D 3	D 4	Mean
Pant 209	8.15	5.80	2.75	1.45	4.54	42.45	30.10	5.40	3.80	20.44
Pant 406	10.10	5.00	2.45	1.57	4.78	37.20	32.25	5.00	2.90	19.34
LG 112	7.55	4.10	3.30	0.75	3.92	36.35	27.50	3.40	2.95	17.55
L 9-12	10.55	4.55	2.45	1.95	4.87	28.60	35.70	6.50	3.50	18.57
Mean	9.09	4.86	2.74	1.43		36.15	31.39	5.07	3.28	
C. D. at 5 % for dates of sowing		=			1.746					4.399
C. D. at 1 % for dates of sowing		=			N.S.					5.903

After one month of the first observation aphid population was comparatively high in all the cultivars under test. However, there was no significant difference in pest population in between the cultivars. Again differences in aphid population on different dates of showing were significant. Population of aphid was significantly low in D 2, D 3 and D 4 in comparison to D 1. Similarly, it was significantly low in D 3 and D 4 in comparison to D 2.

CONCLUSIONS

It is therefore concluded that lentil crop sown in the beginning of November has significantly high population of the black aphid, *A. craccivora* in comparison with the crop sown in the end of November and the first fortnight of December.

B. Incidence of black aphid on some promising cultivars of lentil

Two lentil cultivars viz., P 927 and P 202 which have been isolated to be resistant against the pod borer, ***Etiella zinckenella*** T. (Chhabra and Kooner, 1978) out of more than 800 cultivars were tested in the field along with the standard L 9-12, the locally recommended variety, for the incidence of ***A. craccivora.*** Each test cultivar was sown on 17.11.78 in a block of 120 sq. m. Observations to record the incidence of aphid were taken when the pest population was at its peak (3.3.79). To record the aphid population, ten plants in each block were selected at random. Aphid population on each plant was recorded as per method detailed in experiment 'A' above. The data so recorded are presented in table 2.

RESULTS AND DISCUSSION

From the data presented in table 2, it is revealed that population of the black aphid in the cultivar P 927 ranged in between 0 to 4 per plant. The mean population was 1.3 per plant. In the case of P 202, it fluctuated between 0 and 6 per plant. The mean pest population in this case was 2.4 per plant. Population of black aphid in the standard cultivar, L 9-12 ranged in between 3 to 11 per plant. As such the mean aphid population was 6.6 per plant.

CONCLUSIONS

It may, therefore, be concluded from the obtained data, that the incidence of the black aphid in the two cultivars under test, P 927 and P 202, is significantly low in comparison to the standard L 9-12.

TABLE 2

Incidence of black aphid, ***Aphis craccivora*** Koch on some promising lentil cultivars.

Cultivar	Black aphid population										Mean aphid population per plant
	Plant number										
	1	2	3	4	5	6	7	8	9	10	
P 927	0	0	2	1	2	0	2	4	2	0	1.3
P 202	0	2	2	1	4	1	3	1	6	4	2.4
L 9-12 (Standard)	5	4	6	3	5	10	8	10	4	11	6.6
C. D. at 5 %											1.799

C. Screening of blackgram germplasm material against the black aphid

107 cultivars of blackgram gremplasm were sown on 18.7.78 in paired rows of 3 meter in length to screen against *A. craccivora.* These cultivars were also screened against the whitefly, ***Bemisia tabaci*** G., jassid, ***Empoasca kerri*** P., pod borer complex, ***Lempides boeticus*** L., and ***Heliothis armigera*** H. and Yellow Mosaic Virus (YMV). Grading for screening against black aphid was done when the pest activity was at its peak (15.9.78). The whole material was graded in three categories as under :

1. Free : No aphid population on any plant.
2. Moderately susceptible : Aphid colony counting 1 to 10 aphids per plant.
3. Highly susceptible : Aphid colony counting 11 and more aphids per plant.

Grading was thus done on visual basis. Grades scored by the various test cultivars have been detailed in table 3.

RESULTS AND DISCUSSION

From the data it it revealed that out of 107 cultivars under screening against ***A. craccivora***, more than 50 per cent (79) material was free from the incidence of this pest. In the category moderately susceptible 12 entries were recorded. Highly susceptible category had 16 entries. Taking into account the overall performance of the entries, which had scored "Free grade" in black aphid screening in relation to screening against

TABLE 3

Incidence of black aphid, *Aphis craccivora* Koch in blackgram germplasm material.

Aphid incidence grade	Germplasm cultivar								
Free	LU 4,	LU 5,	LU 6,	LU 7,	LU 9,	LU 14,	LU 15,	LU 18,	LU 27,
	LU 41,	LU 65,	LU 71,	LU 76,	LU 79,	LU 82,	LU 83,	LU 89,	LU 98,
	LU113,	LU123,	LU126,	LU127,	LU150,	LU154,	LU178,	LU184,	LU188,
	LU189,	LU190,	LU192,	LU194,	LU196,	LU204,	LU211,	LU219,	LU221,
	LU227,	LU263,	LU270,	LU294,	LU299,	LU302,	LU313,	LU317,	LU318,
	LU322,	LU329,	LU334,	LU353,	LU365,	LU398,	LU402,	LU423,	LU426,
	LU428,	LU429,	LU434,	LU440,	LU460,	LU463,	LU466,	LU467,	LU478,
	LU500,	LU517,	LU522,	LU524,	LU525,	LU526,	LU527,	LU528,	LU535,
	LU536,	LU537,	LU538,	LU539,	LU540,	LU541,	M 1-1	(Total 79 entries).	
Moderately susceptible	LU240,	LU242,	LU258,	LU274,	LU301,	LU320,	LU330,	LU332,	LU335,
	LU392,	LU396,	LU397	(Total 12 entries).					
Highly susceptible	LU186,	LU205,	LU212,	LU218,	LU264,	LU282,	LU338,	LU354,	LU355,
	LU356,	LU357,	LU391,	LU469,	LU470,	LU504,	LU513	(Total 16 entries).	

Free : No aphid on any plant.
Moderately susceptible : Aphid colony 1-10 aphid/plant.
Highly susceptible - Aphid colony 11 and above/plant.

whitefly, jassid, YMV and pod borer complex, cultivar LU 178 excelled. However, three more cultivars viz., LU 15, LU 190 and LU 194 were next to the best.

CONCLUSIONS

Out of the 107 cultivars under screening against *A. craccivora*, 79 cultivars were recorded free from the incidence of this pest against 12 and 16 in the category of moderately susceptible and highly susceptible respectively. In overall performance taking into account the screening against whitefly, jassid, YMV and pod borers, cultivar LU 178 was the best followed by three cultivars LU 15, LU 190 and LU 194.

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SEASONAL INCIDENCE AND TOXICOLOGICAL STUDIES ON *LIPAPHIS ERYSIMI* (KALT.) AND ITS PARASITE, *APHIDIUS* SP. (?) IN MADHYA PRADESH, INDIA

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ABSTRACT

Studies on the seasonal incidence of the mustard aphid, *Lipaphis erysimi* (Kalt.) and its parasite, *Aphidius* sp. (?) on mustard (*Brassica juncea* — variety "Varuna") were undertaken in two consecutive years of 1977-78 and 1978-79 at Jabalpur, Madhya Pradesh, India. Sparse population of adult winged aphids started from the first week of January in both years and the pest multiplied slowly upto the end of January. A sudden spurt in the aphid population was recorded in the first week of February which reached its peak in the third week of February, when population ranged from 139 to 225 (mean 163.90) / 10 cm apical twig. The aphid population declined sharply in the last week of February and the pest disappeared completely in the first week of March in 1978 and second week of March in 1979.

The endoparasite, *Aphidius* sp. (?) started its activity in the second week of January in 1978 and in the third week of January in 1979. It parasitized 48.20 % and 17.16 % aphids in the first week of February, 1978 and 1979, respectively and the parasitisation reached above 80% and 90% in the third and fourth week of February in both years. In March both host and parasite disappeared.

Toxicity of 22 insecticides was worked out against *L. erysimi* and its parasite, *Aphidius* sp. (?) in the laboratory under Potter's tower to elucidate effective insecticides against the aphid but safer to its parasite. Dichlorvos (0.04 %), chlorpyrifors (0.04 %), methyl-parathion (0.05 %), phenthoate (0.05%) and diazinon (0.025%) were found highly toxic to the parasite in the mummies and inflicited 100.00 %, 100.00 %, 96.66 %, 96.66 % and 96.66 % parasite mortality respectively. Endosulfan (0.07%), phosalone (0.035 %) and methyl-demeton (0.025 %) were found comparatively less toxic and at par with one another, inflicting 20 %, 30 % and 33.33 % mortality of parasites in mummies respectively.

All insecticides tested were found highly toxic at the concentrations used, to the aphid and recorded 100 % aphid mortality.

Based on their selective action, endosulfan, phosalone and methyl-demeton are therefore recommended for the control of the pest and to spare its important parasite.

INTRODUCTION

Mustard (*Brassica* spp) is a principal oilseed crop of India. Of its various pests, *Lipaphis erysimi* (Kalt.) is the most serious and regular menace resulting in tremendous loss to grain yield and sometimes due to its severe infestation the crop dies pre-maturely. The endoparasite, *Aphidius* sp. (?) was first recorded parasitising this aphid in the *rabi* season of 1978 at Jabalpur, Madhya Pradesh, India. No literature is available on the parasites of *L. erysimi* from Madhya Pradesh. Kundu *et al* (1966) reported for the first time in India, *Diaeretiella* (*Aphidius*) *rapae* (M' Intosh) as an endoparasite of *L. erysimi* from Uttar Pradesh and West Bengal. Later, Sethumadhavan and Dharmadhikari (1969) reported it on *L. erysimi* and *Brevicoryne brassicae* from Uttar Pradesh, Assam, Punjab, West Bengal, Himachal Pradesh and Kashmir and gave its seasonal occurrence and life history. Little work has been done in India on the seasonal incidence and toxicological studies on *Aphidius* spp., though much work has been done on these aspects on their host aphids. Atwal *et al* (1971) worked out the seasonal incidence of *L. erysimi* and its parasite *D. rapae* in Punjab. Obrtel (1961) and Wiackowski and Dronka (1968) tested some insecticides against *Aphidius ervi* and *Diaeretiella rapae* in Czechoslovakia and Poland respectively. Radhke and Barwad (1978) worked out the toxicity of some insecticides against the living mummies of *Aphidencyrtus aphidovorous* (Mayr).

The present studies were undertaken on the seasonal incidence of *L. erysimi* and its endoparasite, *Aphidius* sp. (?) and toxicity of available insectidides against them at Jabalpur, with a view to determine the selective insecticides which would spare the parasite but at the same time effectively control the aphid pest.

MATERIALS AND METHODS

To study the seasonal incidence of *L. erysimi* and its parasite, mustard (*Brassica juncea* variety — "Varuna") was sown in a plot of 10 m × 10 m at intervals of 10 days starting from September 25 to December 25 in 1977 and 1978 crop seasons. Observations on the populations of the aphid and its parasite were recorded on 10 cm long 30 apical twigs / plot, at intervals of one week. Percentage parasitisation was ascertained by counting the healthy and mummified aphids. Data on maximum temperature were obtained from the observatory, J. N. Agril. University, Jabalpur.

For toxicological studies commercially formulated 22 insecticides (Table 1) having different modes of action were tested at their recommended concentrations in the laboratory under Potter's tower. Four ml prepared solution of each insecticide was atomized at a pressure of 2 kg / cm^2 on each 15 cm diam., petri dish containing 10 healthy and 10 mummified aphids. Each treatment was replicated four times. Aphids and the mummies were collected from the untreated mustard fields and seasoned for 24 hrs in the laboratory before treatment. After the spray petri dishes were kept under ceiling fan for about 15 minutes for drying. Then the sprayed aphids and the mummies were transferred to fresh petri dishes with fresh apical mustard plant twigs. Observations on the aphid mortality were recorded after 72 hrs of spray. For parasite mortality, observation on the adult parasite emergence was recorded after 7 days of spraying, and subsequently percentage mortality of mummies was calculated for each treatment. The data were subjected to statistical analysis.

RESULTS AND DISCUSSION

Seasonal incidence of L. erysimi and *Aphidius* sp. (Table 1, Fig. 1)

The migratory winged aphid population started infesting mustard plant from the first week of January in both the years of 1977-1978 and 1978-1979 when the aphid population ranged from 7.00 to 14.30 (Mean 8 93) and zero to 1.70 (Mean 0.19) / 10 cm long apical twig, respectively. Very slow multiplication of the pest was recorded up to the fourth week of January when only 20.46 to 78.30 (Mean 40.46) and 14.70 to 43.10 (Mean 38.39) aphids / 10 cm long twig were recorded in 1978 and 1979, respectively. A sudden spurt in the increase of aphid population (Fig. 1) was observed in the first week of February in both the years when aphid population ranged from 72.00 to 103.00 (Mean 80.00) and 73.66 to 131.00 (Mean 86.86) per 10 cm long twig in 1978 and 1979 respectively. The aphid population was at its peak in the third week of February in both the years (Fig. 1), ranging from 112.00 to 160.00 (Mean 148.00) and 139.00 to 225.00 (Mean 163.00) per 10 cm long apical twig in 1978 and 1979, respectively. A sudden decline in the aphid population was observed in the fourth week of February in both the years 1978 and 1979, showing only 2.32 to 8.60 (Mean 4.32) and 8.00 to 36.00 (Mean

TABLE 1

Seasonal incidence of ***Lipaphis erysimi*** (Kalt.) and its parasite, ***Aphidius*** sp. (?) at Jabalpur.

Period of observation	Week	Year	No. of aphids/10cm twig		Percentage parasitization		Temperatures (°C) maximum
			Range	Mean	Range	Mean	
January	I	1978	7.00 — 14.30	8.93	00	00	20.57
		1979	00 — 1.70	0.19	00	00	25.15
January	II	1978	12.32 — 18.30	13.34	00 — 6.72	2.10	21.42
		1979	2.00 — 8.10	3.74	00	00	26.80
January	III	1978	18.20 — 40.00	19.30	00 — 8.90	4.70	25.61
		1979	3.66 — 18.66	26.16	00 — 4.65	1.80	24.44
January	IV	1978	20.46 — 78.30	40.46	5.00 — 29.30	20.30	20.80
		1979	14.70 — 43.10	38.39	3.69 — 8.20	5.68	23.46
February	I	1978	72.00 — 103.00	80.00	15.30 — 54.80	48.20	23.24
		1979	73.66 — 131.00	86.66	5.20 — 41.00	17.16	21.97
February	II	1978	110.32 — 140.00	130.00	40.00 — 62.30	58.16	23.88
		1979	134.00 — 210.00	180.40	50.00 — 90.47	69.37	23.20
February	III	1978	112.00 — 160.00	148.00	62.00 — 98.30	83.68	23.98
		1979	139.00 — 225.00	163.90	64.00 — 100.00	81.11	27.20
February	IV	1978	2.32 — 8.60	4.32	72.30 — 100.00	91.00	25.00
		1979	8.00 — 36.00	18.00	86.66 — 100.00	96.47	27.18
March	I	1978	*	*	*	*	29.35
		1979	2.00 — 18.34	7.23	95.00 — 100.00	97.50	28.61

* Aphid populatisn disappeared from the field.

18.00) aphid per 10 cm long apical twig respectively. Aphid population disappeared completely in the first week of March in 1978 and in the second week of March in 1979 (Fig. 1) because of high parasitisation.

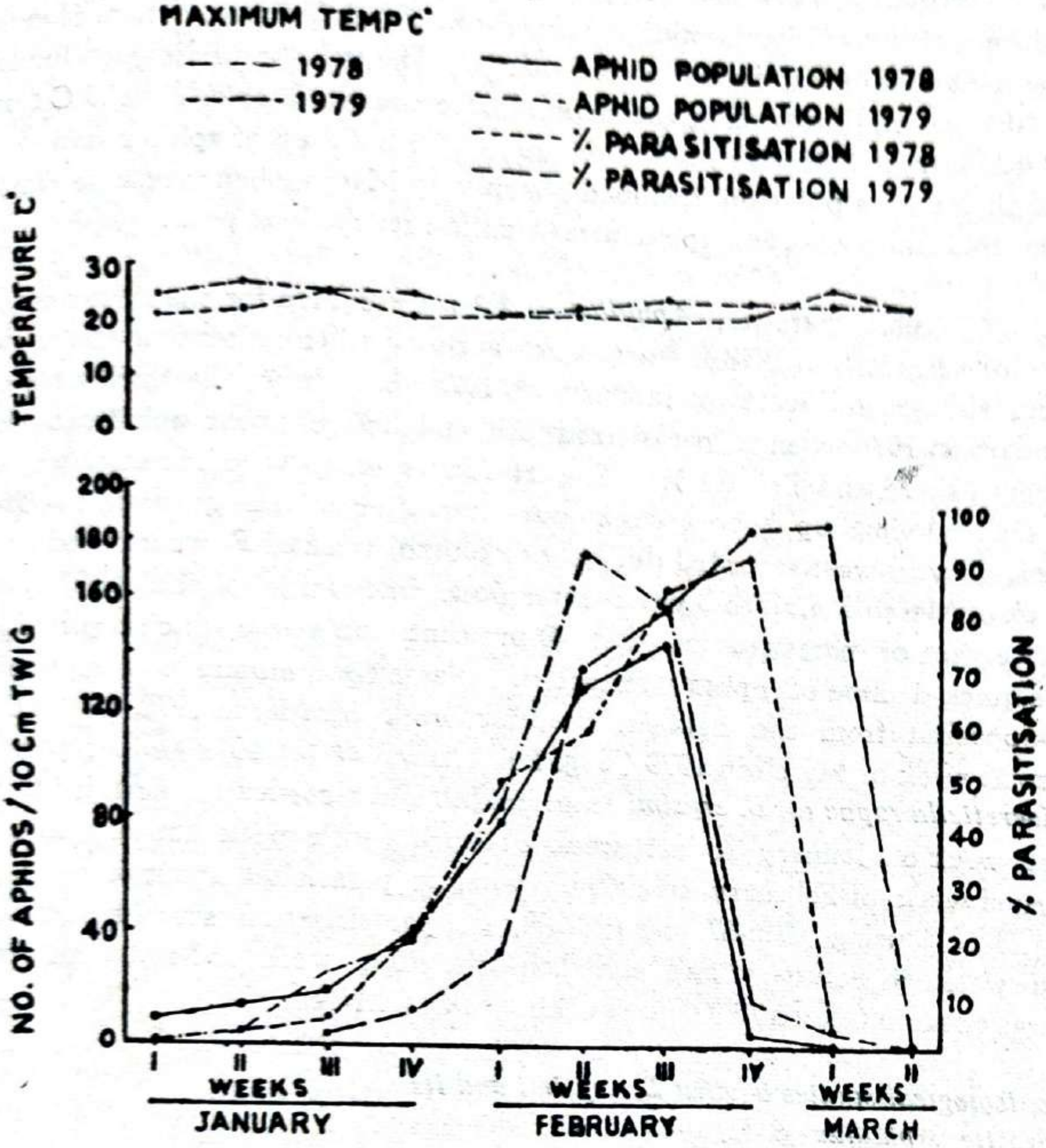

Fig. 1- SEASONAL INCIDENCE OF LIPAPHIS ERYSIMI AND ITS PARASITE, APHIDIUS SP. (?) AT JABALPUR (M.P.) ON MUSTARD

Atwal and Sethi (1963) and Atwal *et al* (1971) reported peak infestation of mustard aphid in the first or second half of February in the Punjab. Atwal *et al* (1971) also stressed that above 30°C the decline in aphid population was very sharp. Sarup *et al* (1961) and Sidhu and Singh (1964) observed maximum aphid population between January to March. Sachan and Srivastava (19.2) reported low population of the pest up to December, which increased gradually reaching its peak by the end of February, the population remained high up to March after which it started declining. They further observed that maximum temperature between 23.9 and 32.0°C and maximum relative humidity between 60.7 and 72.3 per cent are favourable for aphid multiplication in Rajasthan. The present studies conducted at Jabalpur indicated that the maximum temperature of 20°C to 25°C (up to 3rd week of February) was favourable for build up of aphid infestation and that the population declined sharply in March when maximum temp. was 28°C and above, and aphid parasitization reached its peak.

Aphid parasite, *Aphidius* sp. (?) (recorded for the first time in Madhya Pradesh in 1978) started its activity a little later than the aphid from the second week of January in 1978, and from the third week of January in 1979 when it parasitized 2.10 and 1.80 per cent aphids, respectively (Fig. 1 and Table 1). The rise in its activity was relatively slow in the beginning up to two weeks but thereafter it was quite fast. The peak activity was recorded during the fourth week of February and first week of March i. e., 2 to 3 weeks after peak infestation of the aphid when the extent of parasitisation was 90 per cent and above which resulted in the quick decline of aphid infestation. Parasitised mummies completely disappeared from the field in the first week of March 1978 and in the second week of March in 1979 (Fig. 1). Atwal *et al* (1971) also reported *Diaeretlella rapae* on *L. erysimi* from Punjab and recorded its activity from last week of January to last week of April, with peak activity in the second week of February in 1965-66 when it parasitised about 60 per cent aphids. During 1966-67 and 1967-68, its parasitisation started from the 3rd week of February and ended in the first week of May, with peak parasitisation (60 to 70 %) in the 3rd week of March.

Toxicological studies against L. erysimi and its parasite, Aphidius sp. (?)—

Twentytwo commercially formulated insecticides (Table 2) were tested in their recommended doses against the healthy apterous adult aphids and living mummies of parasitised aphids under Potter's tower. Against aphids, all insecticidal treatments gave 100 % mortality. According to the mortality of the parasite in the mummies, the insecticides could be placed in four groups. First group of insecticides consisted of dichlorvos, chlorpyrifos, methyl parathion, phenthoate and diazinon which were highly toxic to the parasite inflicting 96.66 to 100 per cent mortality. Second group, which was comparatively less toxic,

TABLE 2

Toxicity of some insecticides against *Aphidius* sp. (?) a parasite of *Lipaphis erysimi* (Kalt.)

Sl. No.	Insecticides	Formulations	Conc. (%)	Percentage mortality
1.	Dichlorvos	Nuvan 100	0.04	100.00 (90.00)
2.	Chlorpyrifos	Dursban 200	0.04	100.00 (90.00)
3.	Methyl parathion	Metacid 50 EC	0.05	96.66 (83.85)
4.	Phenthoate	Elsan 50 EC	0.05	96.66 (83.85)
5.	Diazinon	Basudin 25 EC	0.025	96.66 (83.85)
6.	Fenthion	Lebaycid 1000	0.04	83.33 (70.07)
7.	Aldrin	Aldrin 30 EC	0.03	86.66 (70.07)
8.	Fenitrothin	Sumithion 50 EC	0.05	86.66 (68.85)
9.	Malathion	Cythion 50 EC	0.05	86.66 (68.85)
10.	Formothion	Anthio 25 EC	0.025	86.66 (68.85)
11.	Monocrotophos	Nuvacron 40 EC	0.04	86.66 (66.14)
12.	Phosphamidon	Dimecron 100	0.04	80.00 (54.78)
13.	DDT	DDT 50% W. P.	0.1	80.00 (54.78)
14.	Quinalphos	Ekalux 25 EC	0.025	60.00 (50.93)
15.	Vamidothion	Kilval 40 EC	0.04	60.00 (50.85)
16.	Dicrotophos	Bidrin 24 EC	0.024	53.33 (47.00)
17.	Dimethoate	Rogor 30 EC	0.03	50.00 (46.92)
18.	Malathion	Malataf 50 EC	0.05	46.66 (43.07)
19.	Carbaryl	Sevin 50 % W. P.	0.1	43.33 (41 15)
20.	Methyl demeton	Metasystox 25 EC	0.025	33.33 (35.01)
21.	Phosalone	Zolone 35 EC	0.035	30.00 (33.00)
22.	Endosulfan	Thiodan 35 EC	0.075	20.00 (26.57)
23.	Control	Untreated	—	13.33 (21.14)
	S. Em	—	—	— (4.54)
	C D at 5%	—	—	— (12.97)

included fenthion, aldrin, fenitrothion, malathion (cythion) formothion, monocrotophos, phosphamidon and DDT (W. P.) which recorded 53.33 to 83.33 per cent mortality. The third group included quinalphos, vamidothion, dicrotophos, dimethoate, malathion (Malataf) which recorded 46.66 to 60.00 per cent mortality. The fourth group of insecticides included carbaryl (W. P.), methyl demeton, phosalone and endosulfan which were least toxic inflicting 43.33, 33.33, 30.00 and 20.00 per cent mortality respectively. Endosulfan, and phosalone were at par with the control, however, no significant difference was observed among endosulfan, phosalone and methyl demeton which could therefore be included in the integrated control programme of the mustard aphid. Obrtel (1961) reported demeton and malathion to be highly toxic against the adult *Aphidius ervi*. Wiackowski and Dronka (1968) found malathion, formothion, methyl—parathion, and thiodemeton highly toxic while methyl demeton and methyl—DDT comparatively less toxic against the adults of *Diaeretiella rapae*. Radhke and Barwed (1978) reported endosulfan, malathion, quinalphos and carbaryl as safer insecticides against the parasitised aphid mummies of *Aphidencyrtus aphidivorous* (Mayr.), a parasite of *Rhopalosiphum maidis* (Fitch).

ACKNOWLEDGMENT

The authors are thankful to Mr. H. P. Kurmi for his assistance during observations.

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Before every spraying, 100 strokes were given to build up desirable pressure in the tank. At different water volumes (500, 700, and 750 litres/ha), 100 strokes developed 2.3, 2.8 and 3.38 kg/cm^2 pressure respectively. The discharge rate at these varying pressures was 440, 450 and 470 ml/minute respectively. The average pressure fall was also recorded which was 0.3 kg/cm^2 per minute.

Foot Sprayer :

Foot sprayer is operated by foot instead of hand. The trade name of this sprayer is MARUTI FOOT MRT-6. Adjustable type of nozzle (cone spray) with code number ASPEE BAN 75450 is provided with the equipment The diameter of the cap orifice is 1.49 mm. In this case, the pressure is developed due to hydraulic action of pump in the pressure chamber. The pressure fluctuated from 3.5 to 4 kg/cm^2 during operation. The discharge rate worked out was 500 ml per minute. The nozzle was set to produce cone type of spray at the time of spraying.

Knapsack Sprayer :

This sprayer is made up of poly-thelene material and emits spray on the hydraulic action of the pump. Its trade name is ASPEE Napsak SRP-50. The capacity of the tank is 16 litres. The nozzle bearing code number NMM 60450 produces a fine cone spray. The cap orifice has a diameter of 1.19 mm. The fluctuation of pressure was found to be from 2.5 to 3.5 kg/cm^2 during operation. The discharge rate was 480-500 ml/minute and this variation was due to different quantity of spray liquids poured into the tank at the time of operation. A plastic agitator is provided in the equipment.

Water Volume :

Spray volumes evaluated in this study are generally used by various workers for applying pesticide in hectare area. Three varying spray volumes were selected in this experiment for application of insecticide by each sprayer. Spray applications with mist-blower (low volume) was done at the rate of 50, 75 and 100 litre water/ha, while high water volume applications each with a hand compression, foot, knapsack sprayer was done at the rate of 500, 750 and 1000 l/ha respectively. For the sake of convenience all the above varying volumes of spray fluids used in the different spraying equipments have been categorised as low, medium and high. The datails are mentioned below.

Sprayer	Water volumes in litres/hr		
	Low	Medium	High
Mist blower	50	75	100
Hand compression	500	750	1000
Foot	500	750	1000
Knapsack	500	750	1000

As such selected dose of the insecticide was applied in three volumes of water by each sprayer.

Experimental :

The field experiment was laid out in a factorial randomised block design during 1975-76 at Government Farm, Varanasi (India). There were 13 treatments (including control) and each was replicated four times. The plot size was 4.00 m × 6.20 m. The distance between replication to replication was 1 m and plot to plot was 0.75 m. *Raya (Brassica juncea* Coq.) variety T 5909 was sown on the 22nd October, 1975 at a distance of 40 cm between line to line. The insecticide, Malathion as cythion 50 E was applied @ 0.6 kg a. i./ha on the 28th December, 1975 against the mustard aphid, *Lipaphis erysimi* at flowering stage of the crop with plant height from 1.9 to 2.5 m. The same dose of insecticide was applied in 3 varying volumes of water by each sprayer. Equal and uniform coverage was adjusted with the operator's speed and timing as no mechanism is provided in these equipments for the same.

For recording observations on aphids, 10 lightly infested plants were selected at random from 3 central rows of each plot and were labelled. On these, a 10 cm lenth was marked off thread on the top portion of the branch/shoot of each plant for counting the aphid population. At the time of selection, the plants which had countable number of aphids were choosen, while in heavy infested cases, surplus aphids were removed with the help of a camel hair brush. The aphid (adult and nymph) population from these selected areas was counted before, and 24 and 48 hours after spraying. The mortality in terms of per cent reduction of the pest was worked out. The data so obtained were transferred to arc-sin values and were statistically analysed by two table method.

RESULTS AND DISCUSSION

The per cent reduction of the pest was the basis for evaluating the treatments. The various data on the performing of sprayers and influence of spray volumes are given in Table 1 and 2 respectively.

TABLE 1

Performance of sprayers with Malathion against the mustard aphid, *Lipaphis erysimi* (Kalt.)

Sprayer	Mean percent reduction after spraying (hrs)*	
	24	48
Hand compression	88.35 (73.61) +	88.83 (75.52)
Knapsack	83.89 (69.19)	84.30 (70.53)
Mist blower	66.48 (56.43)	74.27 (62.07)
Foot	66.27 (56.62)	67.77 (58.56)
C. D. (P = 0.05)	11.37	N. S.
(P = 0.01)	15.20	N. S.

+ Figures in parentheses are arc-sin angles for percentage values.

* Mean of 4 replications.

Sprayers :

The results recorded after 24 hours of treatment showed that hand compression gave highest mean reduction (88.35 per cent) of aphids followed by knapsack sprayer (83.89 per cent) and was significantly superior to Mist-blower and foot sprayer. the degree of pest reduction observed after 48 hours of treatment denoted that all the sprayers behaved similarly in their performance (Table 1). The average effect of combination of treatments was significant over control in reducing the pest.

The overall results showed that hand compression was better in performance in registering highest mean reduction (88.33 per cent) of the pest. Varma and Mirajgonkar (1972) also reported better distribution of dyes deposit with hand compression in comparsion to low volume carrier on grape. With DDT (1.2 Kg/ha) all the six hand operated machines with various amounts of spray suiting to individual sprayers gave the same level of pest control against larvae of *Heliothis armigera* and *Earias fabia* on cotton. Ananthakrishnan (1963) in his tests showed that a motorised knapsack mist-blower was better than a knapsack sprayer for applying DDT against *Helopeltis* sp. on tea, but it was not always better for applying Chlorobenzilate (Akar 338) against mites.

Water volumes :

Table 2 illustrates the influence of spray volumes on the degree of pest control. It is denoted from table 2 that after 24 hours of treatment, high volume resulted in highest reduction (75.98 per cent) in comparison to low (74.92 per cent) and medium (72.92 per cent) water volumes. When examined after 48 hours of application it was found that statistically there was no significant difference in the influence of varying water volumes in the reduction of aphid population. Apparently, medium volume of spray fluids showed highest reduction (86.49 per cent) of the pest.

TABLE 2

Influence of water volumes with Malathion against the mustard aphid, *Lipaphis erysimi* (Kalt.)

Water volume	Mean per cent reduction after spraying (hrs.)*	
	24	48
Low	74.92 (65.22) +	78.92 (67.43)
Medium	72.59 (65.34)	80.49 (68.70)
High	75.98 (61.34)	76.97 (63.89)
C. D. (P = 0.05)	N. S.	N. S.

\+ Figures in parentheses are arc-sin angles for percentage values.
* Mean of 4 repliaations.

The overall results on the influence of water volumes showed no definite trend in the reduction of aphid population. Singh and Khengura (1975) also reported that the persistence of insecticides applied by high, low and ultra volume methods did not reveal any definite trend in the control of jassids on potato. Sidhu and Singh (1964) in a chemical trial against mustard aphid found that Lindane gave better result in low volume in comparison to high volume on *raya* while it was erratic on *sarson* in two seasons. These findings support the present observations. Singh and Mann (1977) also reported that with Dimethoate the volumes can be reduced from 1000 to 500 l/ha against mustard aphid on mustard crop.

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INSECT PEST MANAGEMENT STUDIES IN *BRASSICA* CROP WITH PARTICULAR REFERENCE TO *LIPAPHIS ERYSIMI* (KALT.)

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ABSTRACT

Information basically required to evolve a suitable pest management strategy against *Lipaphis erysimi* (Kalt.) on rape seed and mustard is discussed.

INTRODUCTION

Rapeseed and mustard are important oilseed crops in our national economy. The average yields on a national scale however are very low being upto 5 qt./ha. One of the reasons for such low yields is the constraint put up by the insect pest complex of this crop. Although more than two dozen insects have been associated with the crop (Rai, 1976) only three are regarded as major pests. They are the mustard saw-fly ***Athalia proxima*** Klug., the painted bug ***Bagrada cruciferarum*** Kiru. and the mustard aphid ***Lipaphis erysimi*** (Kalt.). The first two pests occur only in the early stages of crop growth, but the mustard aphid appears on the crop for a considerable period of plant growth and incurs serious loss even upto 90-95 per cent.

Considering the seriousness of the aphid pests, attempts have been made to control it by the use of chemicals and a perusal of literature shows a large number of references on this aspect (Pal *et al*, 1971; Gupta, 1971). However, taking into consideration the hazards involved in the use of insecticides and the problem of residue left within the plant system, an emphasis is being given to use them to a bare minimum by supplementing other methods of control in a harmonious way. This method of approach also helps in the least upsetting of balance in nature. This trend has given rise to the concept of evolving integrated pest management system based on sound ecological basis for different crops (Geiger, 1966; Rabb, 1972; Stern *et al*, 1959).

As far as rapeseed and mustard crops are concerned, no attempt has however been made in this direction. Keeping this in view, various aspects of the studies which should be undertaken on priority basis are enumerated below.

1. Basic Ecological studies

While considering the effect of climate on insects, a physiological summation of a multitude of environmental factors is dealt with which interact reinforcing or opposing one another or act independently (Lamb, 1961). The last factor is very important while dealing with a highly specialized obligatory pest like aphids or for that matter any insect since these are poikilothermic. In general very low temperature retards the growth and development while higher temperature favour it upto a certain limit. Under field conditions, an insect, for example, the aphid, is subjected to temperature variations, and the effect of these fluctuating temperatures for any given day are expressed against the mean or average temperature obtained for that particular day, which is precisely not correct. The time spent by an insect at different temperatures has to be taken into account. This could be affected by integrating the temperature curve with time and expressing the results as day-degrees. This is a more precise physiological time-scale for expressing the aphid population increase.

In order to meet the above requirement, threshold of developmental temperature for this aphid pest must be known, Despite the fact that *L. erysimi* is a vary serious pest, available literature from India does not show studies on this aspect. There is only one reference from Japan where threshold of developmental temperature for *Rhopalosiphum pseudobrassicae* has been quoted as 7°C (Kawade, 1964).

Apart from temperature, other abiotic components especially humidity and photoperiod are equally important in the life economy of this pest. No information is available on the effect of these constant and variable parameters both separately and in different combinations together. Such studies are therefore very much necessary in order to understand the exact role of these factors on the population increase.

More accurate estimate of determining the changes in aphid numbers has been described by Hughes (1962, 1963). Such studies are based on the ratio of different age groups in population sample and are applicable in case of those insects whose generations widely overlap i. e., with a multistage population in which practically all stages are found at any time. The rates of increase found between the number of aphids in successive instars represent the potential rate of increase. Such a study primarily involves determining the duration of instar periods, and the size of the sampling unit. An analysis of the instar distribution within the sample (assuming duration of instars to be equal) enables the estimation of potential rate of increase, the overall mortality rates and reproductive rates of the adults from the field population. Studies on these lines should be extended in case of mustard aphid also.

2. *Natural abundance and persistence of pest population*

In order to make use of pest management to the best advantage, an understanding of the natural influence which determines abundance and persistence of insect population is very much essential. Under natural conditions, pest population always fluctuates around an equilibrium level depending upon the environmental resistancy. Any release in enverinmental resistance results in the sudden upsurge of insect population. It is therefore very much necessary to identify those parameters which influence the increase or decrease in population in order to devise a model to anticipate the expected intensity of the pest attack. In case of mustard aphid, if the expected intensity of aphid attack could be visualized in the beginning, suitable methods to minimize the losses could be devised by proper manipulation, timely control, or by recommending sowing of varieties which are tolerant to aphid infestation.

It is a matter of common observation that during some years aphid attack is most serious while in some other years, it is moderate or of a very low magnitude. This suggests that probably the intensity of aphid attack is in some way related to weather factors not only during the crop season but those prevailing even before the main crop season. In this connection, the time of appearance of the first migrants and their intensity are extremely important to make the predictions much earlier as from these migrants population build up starts at a later stage. The rapid multiplication of aphids give the farmer very little time to decide what application method he has to employ for its control. This problem could therefore be solved by basing the warning scheme on aerial populations at an earlier date and linking this to a later population weather forecast. The basic pattern imposed by the weather factors also influences the effectiveness of other biotic factors such as the occurrence of parasites and predators. Forecasting systems thus could be improved by greater understanding of the relationship between trap catches and the field population (Ian McLean *et al.*, 1977).

3. *Aphid infestation and seed yield*

The aphid populations largely influence the yield. The different levels of aphid infestation observed during different years therefore affects the crop yield differently. Thus while understanding the influence of weather factors on the aphid intensity, information on the expected yield with the expected intensity of aphid attack should be available. However, this is possible only when a relationship between aphid intensity and yield is established.

Further, in order to carry out the pest management effectively, knowledge about the critical threshold of aphid population at or beyond which the process of reduction in yield is initiated is very much necessary. Such studies are still lacking on this pest.

Knowing the extent of damage in relation to aphid intensity, information on the time of occurrence of growth stage permits maximum efficiency in pest control. There are two phases of aphid attack. One during the vegetative phase of the crop growth i. e., pre-flowering stage and the other during post-flowering period. The flowering shoot of the mustard plant is the most sensitive part where aphid multiplication rate is very high and accounts largely for reduction in seed yield. However, in case of mustard crop, aphid infestation starts much earlier to flowering. It may be possible that aphid infestation even during the pre-flowering stage (i. e., on leaves, stem, etc.) might initiate the process of yield reduction about which definite information is still needed. Such type of studies should therefore be taken up in detail.

4. *Non-chemical methods of control*

Another very important strategy that needs to be investigated into is to find out the feasibility of non-chemical methods of control. This approach includes physical and cultural methods besides exploring the possibility of using alarm pheromones. The physical methods include (1) use of adhesive traps, and (2) use of reflectors. The cultural methods include (1) altering the date of sowing, (2) use of Trap crop variety and (3) use of resistant varieties.

PHYSICAL METHODS

(i) *Adhesive traps*

A perusal of literature shows that a lot of study has been made to reduce the incidence of winged migrants on the crop by putting yellow coloured water or adhesive traps all around the area, particularly the coastal area, in many of the western countries. Besides, such a device helps in understanding the migrating or dispersal behaviour of the aphids (Kuan *et al.*, 1974).

If such adhesive traps are put around the mustard field at different locations, it is likely to reduce not only the initial establishment of the winged migrants on the crop, but also the subsequent infestation. However, intensive research is needed to find out the optimum height from the ground level and size of the trap, number of traps needed per hectare and efficiency of the trap. Studies should also be carried out to find out the effect of these traps in maximising the seed yield.

(ii) *Reflectors*

Many workers (Johnson *et al.*, 1967; Kring, 1970) have suggested the use of reflectors particularly the aluminium foil reflectors to be used as a mulch. Because of the reflection of sun's rays, the migrant aphid on wing is not able to settle on the crop. The economic feasibility of such a method could be studied by using alternative cheaper reflectors or by spraying the crop by such non-chemical substancess whose deposits may help to repel the alates due to reflection.

CULTURAL METHODS

(iii) *Date of sowing*

A few workers attempted to find out the effect of sowing date on the aphid infestation vis-a-vis yield. Recently a number of new varieties have been released and keeping in view their yield potential, it is worthwhile conducting a few experiments on this aspect. In this connection work on optimum plant population vis-a-vis aphid incidence and yield is equally important.

(iv) Trap crop

The concept of trap crop is not new but need further studies in this crop. It has been demonstrated by some workers that if a crop of ***sorghum*** is grown in between and around the maize crop, it helps in enhancing the maize yield. Since ***sorghum*** is known to be a favoured food of ***Chilo partellus***, infestation in maize is reduced resulting in more yield.

A number of varieties, particularly yellow sarson, are known which are favoured by the aphids for their initial pick up and multiplication. If such cultivars are sown around and in between the crop variety in an orderly way, these may act as traps and the infestation on the main crop could be reduced. Elaborate experimentation is however required in this connection.

(v) Sowing of a resistant variety

Screening of germ plasm to identify relatively resistant sources against aphid attack has to be continued every year for ultimately evolving resistant and agronomically well-suited cultivars. Sowing of such varieties is likely to reduce the losses. Such varieties however are evolved under a free choice test i. e., when other varieties are also available nearby. The stability of resistance when these varieties are cultivated on a large scale as a monoculture has however, to be studied.

(vi) Insect Pollinators

A number of insect pollinators visit the crop for collection of nectar and poll•n or both. Honeybees are predominant amongst these. Varieties of brown sarson are by and large cross pollinated. In such cases, attempts to exploit the use of pollinators, particularly honey bees should be vigorously followed. Further investigations on the number of colonies required per hectare, optimum distance at which the colonies should be kept and methods to increase the efficiency of pollinators are required to be carried out, so that maximum exploitation of pollinators could be usefully blended with the integrated approach for pest management. Investigations on the use of safer insecticides should be conducted to save the pollinators (Kapil, 1971).

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The Aphids : 283-287

EFFECT OF MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.) INFESTATION ON THE SEED YIELD OF DIFFERENT VARIETIES OF *BRASSICA* SPECIES

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ABSTRACT

Studies on the effect of aphid infestation on the seed yield of ten different varieties of *Brassica* species were carried out at the I. A. R. I. farm, New Delhi during 1977-78. The experiment was carried out in a split-plot design with varieties as main treatments and protected and unprotected crop plots as sub-treatments. The maximum aphid infestation on all the varieties in unprotected plots reached at the same time though their incidence differed from variety to variety. The yield loss amongst the varieties ranged from 8.9 to 77.5 per cent. It was found that though some varieties had a higher aphid incidence, yet these suffered less in seed yield. The present studies have thus shown that while considering the varietal responses to aphid attack, yield effects are also very important to evolve a suitable strategy for integrated pest management.

INTRODUCTION

The mustard aphid, *Lipaphis erysimi* (Kalt.) is a serious pest of rape seed and mustard. Of late, a number of varieties of rape seed and mustard have been evolved. The present trend in insect control to minimize the losses lies in evolving a suitable integrated pest management strategy for each crop. In this context knowledge about the response of different *Brassica* varieties to aphid attack and the corresponding effects on their yield is extremely important since higher the seed loss in a variety, more efficient and economical measures of control are called for. With this aim in view the present investigation was carried out during the *rabi* season of 1977-78 with ten different varieties of *Brassica* species.

MATERIALS AND METHODS

Seed of ten varieties viz., YS-Pb-24, YS-B-9, (*Brassica campestris*, var. yellow sarson); BSH-1, BS-113, (*B. campestris* var. brown sarson);

T-9, sangam (*B. campestris* var. toria); RH-30, RLM-198 and Pusa Bold (*B. juncea)* and Benarsi rai (*B. nigra*; dwarf) were procured from oilseed breeders. The seeds were sown on 26 Oct. 1977 in a split plot design with varieties forming the main taeatments and (i) protected and (ii) unprotected plots as sub treatments. Each sub-plot consisted of five rows, 3 metres long with row to row distance of 60 cm. Plant to plant distance was maintained at 25 cm. Protection against the aphid species was provided by spraying Metasystox (0.025 %) after every 20 days (Pal *et al.* 1971; Gupta, 1971). During spraying care was taken to avoid drifting of the insecticide towards the unprotected sub-plots. There were three replications of this experimental plot. One additional plot of each variety was sown the same day, adjacent to the main trial under similar agronomic practices.

Observations on the aphid population in the unprotected sub-plots were taken at regular intervals. For this purpose four adjacent plants in each of the three central rows were tagged for aphid estimation throughout the crop season. Soon after the appearance of aphids on the plants, first observation on the population counts were taken on the tagged plants on 16 October 1978 and repeated every fortnight. Later on, when it became difficult to count the aphids directly their population was estimated according to the method suggested by Pradhan *et al* (1960) and Bakhetia *et al* (1973). The tagged plants were first categorized into different grades ranging from 0 to 5 depending upon the plant appearance and aphid infestation. Three plants of each grade were then selected from the additional plot of the same variety. Aphids were slowly brushed off from them with the help of a camel hair brush into a petri dish and weighed immediately. It was found that on an average 0.01 gm aphid sample contained 40 aphids and from this the number of aphids present on the plant in each grade was calculated. From the grades given to the tagged plant in the experimental plot, the total number of aphids present on twelve plants in each unprotected sub-plot was estimated. The process was repeated at each observation. In the end, data on seed yield were recorded at harvest.

RESULTS AND DISCUSSION

The results on the fluctuations of the aphid population on differens varieties of *Brassica* species throughout the crop season will be dealt with in detail elsewhere by the authors. It was however observed that though the varieties differed in their varietal characteristics, the peak of aphid population reached at the same time that is, on 10 February 1978. The estimated maximum populations reaching the peak are given in Table 1

TABLE 1

Reduction in seed yield due to aphid infestation of *Lipaphis erysimi* (Kalt.) in different varieties of *Brassica* species.

Sl. no.	Variety	Max. aphid population/ plant	Yield in Qt./ha.			Percentage reduction in yield
			Protected	Unprotected	Difference	
1.	YS-Pb-24	23,922.2	14.43	3.25	11.18	77.5
2.	YS-B-9	6,817.7	9.93	4.65	5.28	53.2
3.	BSH-J	14,833.3	17.29	8.92	8.37	48.4
4.	BS-113	7,400.0	20.44	13.47	6.97	34.1
5.	T-9	12,238.8	10.27	3.93	6.34	61.7
6.	Sangam	12,055.5	12.08	4.64	7.44	61.6
7.	RH-30	2,688.8	30-52	26.98	3.54	11.6
8.	RLM-198	2,934.4	25.41	19.74	5.67	22.3
9.	Pusa Bold	3,262.6	26.67	21.02	5.65	21.2
10.	*B. nigra*	2,183.3	7.64	6.96	0.68	8.9
		Mean	17.47	11.35		

C. D. 5 % for

Mean treatment (Variety)	5.22
Subtreatments	0.91
Interaction	2.87

along with the corresponding yields obtained from both unprotected and protected plots. Analysis of the yield data show that effects due to treatments (varieties), sub-treatments (protected and unprotected) and the interaction were all statistically significant. The data further show that the variety BSH-I though supported 14,833 aphids per plant, resulted in the seed loss of 48.4 per cent only whereas the three varieties T-9, sangam, and YS-B-9 with relatively less aphid infestation upto 12,238; 12055 and 6817 aphids per plant resulted in an yield loss of 61.7, 61.6 and 53.2 per cent, respectively. Similarly, though in variety BS-113 aphid infestation was more than YS-B-9, yet it suffered less seed yield loss than the latter. The varietal suitability for the growth of aphid population thus appears to be different from its vulnerability to damage in different varieties. Studies carried out by different workers (Bakhetia and Sandhu, 1973; Rai and Sehgal 1975; Brar *et al* 1976) on the susceptibility of different varieties are based on observations on aphid incidence only. The present studies show that while considering the varietal responses towards aphid incidence, yield effects are also very important to draw any definite conclusion. It is possible that though some varieties might show higher aphid incidence, yet they may suffer less in seed yield due to their ability to withstand the aphid attack.

Amongst the varieties studied, RH-30, BS-113, and YS-B-9 appear to be better than others from rai, brown sarson and yellow sarson groups respectively as reflected from the relatively less seed loss in them. The two toria varieties were almost similar in both aphid infestation and its effect on the yield. The Benarsi rai had the least aphid infestation and yield loss.

ACKNOWLEDGMENTS

The authors are grateful to Dr. K. N. Mehrotra, the then Head of the Division of Entomolog, I. A. R. I.. New Delhi, for providing necessary facilities and guidance in field experimentation.

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The Aphids : 288-294

STUDIES ON THE ECONOMIC THRESHOLD OF THE MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.) ON *BRASSICA JUNCEA* L.

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ABSTRACT

Experiments to work out the economic threshold of the mustard aphid, *Lipaphis crysimi* (Kaltenbach) damaging *Brassica juncea* var. *raya* (RLM 198) were carried out at Ludhiana from 1975-76 to 1977-78. Per cent plants infested with the aphid was the criterion for initiating control measures. Observations were recorded at weekly intervals from December to March. Ten levels i. e., 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 per cent plants infested with the aphid were maintained by spraying with methyl demeton (0.025%), whenever the given level reached/crossed in plots of a particular treatment. The yield obtained at various levels of infestation was on a par with each other and differed significantly from that of the untreated control during all the 3 years. The overall mean increase in yield ranged from 355 to 432 kg/ha in different levels of plants infested and their differences were non-significant. The mean gain over control varied from Rs. 916 at 10 per cent to Rs. 1366 at 80 per cent levels of plant infestation. However, the differences in the gain at 30 to 100 per cent plant infestation were within a narrow range. The need and implications of initiating spray operations at the lower level of infestation have been discussed.

INTRODUCTION

The *Brassica* crops in general are used in many ways such as vegetables, oils, oil-cakes and the raw material for vanaspati industry. Their production is limited to a greater extent due to the losses caused by the aphid, *Lipaphis erysimi* (Kalt.). It can be controlled by the application of insecticides (Saini and Chhabra, 1966; Bindra, 1972 and Bakhetia, 1976). Three sprays at 15-20 day intervals are recommended for the control of this pest in the Punjab (Anonymus, 1979). The recently released *raya* variety (RLM 198) is moderately resistant to the mustard aphid (Bakhetia, 1975; Bakhetia and Bindra, 1977). Also it is very responsive to high fertility and irrigated conditions. This has been widely accepted by the cultivators. The old recommendation of three sprays, therefore, needs to be revised in the light of the changed agrotechnology. Also most of the pesticides are lipophilic in nature. Their use on oilseed crops, therefore, needs to be minimized. This can be achieved through the judicious use of pesticides on the basis of population assessment (economic threshold) of different pests.

The economic threshold of the aphid on mustard crop *(Brassica juncea* var. *rai* or *raya)* has not been determined so far. Studies were, therefore, carried out to develop economic threshold of the aphid on *raya* and the results are reported in this communication.

MATERIALS AND METHODS

The experiments to work out the economic threshold of *L. erysimi* on *raya* variety RIM 198 were carried out at the Research Farm of the Punjab Agricultural University, Ludhiana during 1975-76 to 1977-78. Per cent plants infested with the aphid was the criterion for recording observations. A plant, bearing the aphid colony was accounted as infested. A mother aphid along with 2 or more young ones constituted the aphid colony. Ten levels viz., 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 per cent plants infested with the aphid and an untreated control comprised the experiment laid out in a randomized block design. There were three replcations with a plot size of 8 × 2.4 m. The recommended agronomic practices (100 kg N, 50 kg P_2O_5 and 50 kg K per ha and 3 irrigations) were adopted to raise the crop.

Ten plants during 1975-76 and 20 plants during the subsequent two years selected at random from each plot, were observed at weekly intervals. The infestation levels *per se* were maintained by spraying methyl demeton (0.025 %) in the particular plots whenever the mean per cent plants infested reached/crossed the indicated level. This was continued from mid-December onward. Finally, the yield was recorded. Gain per hectare was calculated by subtracting the cost of insecticide used plus labour charges from the cost of extra yield over control obtained in a particular treatment.

RESULTS AND DISCUSSION

The yield obained in all the levels of infestation maintained during the 3 years of study were equally and significantly higher than that obtained in control. The same trend was observed in case of increase in yield over control (Table 1). The increase in yield over control (504 kg/ha) ranged between 313—457 kg/ha during 1975-76, 298 – 566 kg during 1976-77 and 337—999 kg during 1977-78. The overall increase in yield ranged from 355 at 10 per cent to 432 kg/ha at 80 per cent level of infestation, and the differences were nominal. This may be attributed to the moderate resistance of variety RLM 198 to the aphid (Bakhetia, 1975 and Bakhetia and Bindra, 1977). Hence, it gave equally good yield with one or two sprays as compared to that obtained with 4 or 5 sprays.

As regards the gain over control, it was highest (Rs. 1468/ha) in 60 per cent plant infestation during 1975-76 and was closely followed by that obtained in 70 and 80 per cent plant infestation. During the second year (1976-77), the maximum gain of Rs. 1843/ha was obtained in case of 40 per cent plant infestation and the lowest gain Rs. 683 was at 10 per cent plant level. In the third year (1977-78), the highest gain (Rs. 1731) was obtained wherein 20 per cent plant infestation was maintained. The mean gain over control varied from Rs. 916 at 10 per cent plant infestation to Rs. 1366 in case of 80 per cent infestation. However, the differences in the gain from 30 to 100 per cent level of infestation were within a narrow range. In general one or two sprayings were given to maintain the 30-80% levels of infestation except 3 sprays given during 1977-78 for 30 and 40 per cent levels of infestation.

The number of sprays required to maintain the given levels of percentage of plants infested with aphid varied from 1 to 5 in different years. The economics of the aphid control on the basis of pooled yield obtained in different number of sprays has been summarised in Table 2. The minimum gain over control (Rs. 804) was with 5 sprays followed by Rs. 989 with 4 sprays given to maintain 10 per cent level of infestation. The maximum gain over control (Rs. 1401) was from the plots which received only two sprays and the percentage of plant infestation ranged between 20 and 80 over three years.

The mustard aphid reproduces parthenogenetically at a very fast rate of multiplication during December—January (Singh and Sidhu, 1964). It has also been reported that from mid-February onward the mustard aphid

TABLE 1

Economics of aphid control on ***raya*** variety RLM 198 under different levels of plants infestation by ***Lipaphis erysimi*** at Ludhiana (Punjab)

Per cent plant infested	Increase in yield over control*				Gain over control (Rupees)			
	1975-76	1976-77	1977-78	Mean	1975-76	1976-77	1977-78	Mean
10	431 (4)	293 (4)	337 (5)	355.3	1245	683	821	916.30
20	277 (2)	328 (3)	599 (3)	401.3	836	941	1731	1169.33
30	398 (2)	358 (2)	504 (3)	420.0	1261	1115	1422	1266.00
40	368 (2)	566 (2)	352 (3)	428.7	1156	1843	928	1309.00
50	313 (2)	477 (2)	448 (2)	412.7	964	1532	1313	1269.70
60	457 (2)	477 (2)	360 (2)	431.3	1468	1532	1025	1341.70
70	417 (2)	447 (2)	369 (2)	421.0	1433	1427	1065	1305.00
80	447 (2)	477 (1)	372 (2)	432.0	1433	1601	1064	1366.00
90	244 (1)	477 (1)	361 (1)	394.0	1133	1601	1102	1280.30
100	316 (1)	507 (1)	431 (1)	418.0	1010	1706	1330	1358.70
			Price of produce	@	Rs. 350/Q	Rs. 350/Q	Rs. 325/Q	
			Cost of Insecticide	@	Rs. 60/L	Rs. 60/L	Rs. 60/L	
			Labour charges (3 Labour/ha)	@	Rs. 21/ha	Rs. 24/ha	Rs. 27/ha	

* Yield in control was 504, 1162 and 592 kg/ha respectively from 1975-76 to 1977-78.

Figures in parentheses are the number of sprays given in a particular treatment.

population in the field starts declining due to mortality factors like natural enemies, high temperature and hardness of host tissues (Atwal and Sethi, 1967 and Atwal *et al.*, 1971). It is therefore, apparent that the control of the initial built up of the aphid population is more important. The first spray should therefore be given when 30 per cent plants are infested with the aphid. Owing to the moderate resistance of RLM 198 to mustard aphid and the above mentioned mortality factors, a subsequent spray may not be required. However, if considered necessary, the second spray could be given any time between a range of 30-80 per cent plant infestation without any substantial loss in yield.

TABLE 2

Economics of aphid control on *raya* variety RLM 198 on the basis of pooled yield under different number of sprays given over 3 years (1975-76 to 1977-78).

No of sprays	% plants infested		Increase in yield over control (kg/ha)	Price of yield (Rs./ha)	Cost of insecticide and labour (Rs./ha)	Gain over control (Rs./ha)
	Mean	Range				
5	10	10	337	1180	375	804
4	10	10	365	1278	288	989
3	30	20-40	446	1561	216	1345
2	50	20-80	413	1446	144	14C1
1	90	80-100	416	1456	72	1374

Note : The cost of yield, insecticide and spray operations taken on the basis of 1977-78.

The economic theresholds for adopting chemical control measures against different pests have been reported by Stern *et al.* (1959), Mathews and Tunstall (1968), Van den Bosh *et al* (1971), and Sidhu and Dhawan (1976). Most of the earlier workers based their studies on population density of the target pests. However, Stern (1973) recommended the sprays against *Empoasca solanii* (de Long) on cotton in the Imperial Valley (USA) when the leaves show symptoms of yellowing and reddening. Similarly, Singh *et al.* (1975) recommended that sprays against jassid on cotton in Punjab (India) should be initiated when the leaf-margins show yellowing and curling due to jassid injury.

The criterion followed in the present investigation was the per cent plants infested with the aphid. It appeared to be quite easy and less time consuming. Even farmers could use it for making a decision as to when the spray should be initiated against the aphid pest of mustard crop.

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EFFECT OF DIFFERENT DATES OF SOWING AND COMBINATIONS OF FERTILIZERS ON THE INCIDENCE OF THE MUSTARD APHID, *LIPAPHIS ERYSIMI* (KALT.) AND THE GRAIN YIELD OF MUSTARD

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ABSTRACT

A field experiment, using 'Varuna' variety of mustard (*Brassica juncea*) was laid out in split plot design at Jabalpur (Madhya Pradesh) with five dates of sowing viz., September 25, October 10 and 25, and November 10 and 25, 1978 as main treatments and three fertilizer combinations viz., 60 Kg N + 30 Kg P + 20 Kg K/ha (as per recommendation in package of practices), 60 Kg N alone/ha, and 60 Kg N + 30 Kg P/ha as subtreatments. Irrigations were given as and when needed.

The aphid (*Lipaphis erysimi*) infestation lasted 30 days (from 70 to 100 days age) in the crop sown on the first date (25.9.78), 50 days (from 60 to 110 days age) in the crops sown on the 2nd date (10.10.78) and 3rd date (25.10.78) and also in the crop sown on the 4th date (10.11.78) but starting early from 40 days age. In the crop sown on the 5th date (25.11.78) it started even earlier from the 30 days age. The overall average aphid population per 10 cm long apical twig was found to increase with delay in sowing, ranging from 13.20 in the crop of 1st date of sowing to 52.02 in the crop of the 5th date of sowing. The aphid infestation in the crop of the 5th date of sowing started so early and was so severe that the crop could not be harvested and the plants died out in the preflowering stage. There were no significant differences in the aphid infestation among the different fertilizer combinations.

Considering the grain yield, maximum yield (182 Kg/ha) was recorded with nitrogen plus phosphorus application in the 2nd date of sowing, followed by 145 Kg/ha with the same fertilizer combination in the 1st date of sowing.

INTRODUCTION

Mustard is one of the major oilseed crops of India, including Madhya Pradesh. The mustard aphid, *Lipaphis erysimi* (Kalt.) is the regular and most serious pest of this crop depressing the yield considerably and at times resulting in total crop failure. Singh and Sidhu (1959) reported 95% reduction in mustard yield due to this pest in a field experiment on the control schedule by certain insecticides. Manipulation of date of sowing and application of judicious balanced doses of fertilizers are recognized to be important preventive measures against many crop pests and diseases. Considerable work has been done on the chemical control of the mustard aphid, but chemical control alone poses a number of problems and hence must be integrated with preventive cultural measures and biotic agencies. The incidence of mustard aphid and loss to yield have been reported to be influenced by date of sowing (Tripathi and Singh, 1964), by age of plants (Kundu and Pant, 1968) and by levels of fertilizers, particularly nitrogen and phosphorus (Makhmoor, 1975; Valunjkar, 1976). With the ultimate view to evolve a suitable integrated control schedule against the mustard aphid, a field experiment on mustard was laid out with different dates of sowing and fertilzer combinations to find out the safest period of sowing and best fertilizer combination for minimising the aphid infestation and securing maximum grain yield.

MATERIALS AND METHODS

A field experiment was laid out at Jabalpur (Madhya Pradesh) in split plot design with five dates of sowing viz., 25 September, 10 and 25 October, and 10 and 25 November, 1978 as main treatments (main plots) and three combinations of fertilizers viz., 60 kg N+30 kg P+20 kg K/ha (F_1) (as per recommendations in package of practices of the Vishwa Vidyalaya), 60 kg N/ha (F_2) and 60 kg N + 30 kg P/ha (F_3) as sub-treatments (sub-plots), using 'Varuna' variety of mustard (*Brassica juncea*). The sub-plot size was 5 m × 3 m having five rows with row to row and plant to plant distances of 50 cm and 15 cm, respectively. Plot to plot and replication to replication distances were 1 m and 1.5 m resectively. The experiment had four replications. Full doses of phosphorus and potash were given as basal application in furrows at the time of sowing; nitrogen was applied in two split doses—half as basal application in furrows and the rest one month after sowing as top dressing, followed by flood irrigation. Weeding and irrigation were given as and when required.

Observations on the incidence of the aphid were started with the appearance of the pest and continued at intervals of 10 days by recording the aphid population on 10 cm long 30 apical twigs/plot. The crops of the first, second, third and fourth dates of sowing were harvested on 22 and 30 January, 19 February and 6 March, 1979, respectively. The crop of the fifth date of sowing (25 November) being completely destroyed, was left unharvested. The data on the aphid populations and grain yield in respective treatments were statistically analysed.

RESULTS AND DISCUSSION

Effect of aphid population (Table 1, Figs. 1 & 2)—

In the crop of the first date of sowing, the aphid infestation started quite late i. e., after the crop age of 70 days (podding stage) and continued upto 100 days' age of the crop. The overall average population was 13.20 aphids/10 cm twig which was significantly less than that in the crops of all the subsequent dates of sowing. The peak infestation (19.83 aphids/twig) was on 80 days old crop.

In the crop of the second date of sowing the pest had its first appearance after the age of 60 days (flowering cum podding stage) and the infestation continued upto 110 days' age of the crop, with the peak infestation (78.80 aphids/twig) on 90 days old crop and the overall average population of 24.27 aphids/twig which was significantly higher than that in the crop of the first date of sowing and at par with that in the crop of the third date of sowing.

In the crops of the third and fourth dates of sowing, aphid infestation started after the age of 40 days (flowering stage) and continued upto 90 days' age, with the peak infestation of 86.86 and 90.63 aphids/twig, on 70 days old crop and the overall average population of 31.56 and 40.23 aphids/twig respectively. The population on the crop of the fourth date of sowing was significantly more than that on the crop of the third date of sowing.

The crop of the fifth date of sowing was severely infested in which the pest infestation started much earlier, even after 30 days of age (pre-flowering stage) and continued upto 70 days' age by which time the crop was completely destroyed with the peak infestation (103.78 aphids/twig) on 50 days old crop and the overall average population of 52.02/twig which was significantly higher than that on the crops of all the previous dates of sowing.

The subtreatments viz., fertilizer combinations did not differ significantly from one another in relation to aphid infestation showing the overall average of 31.82 to 32.67 aphids/twig.

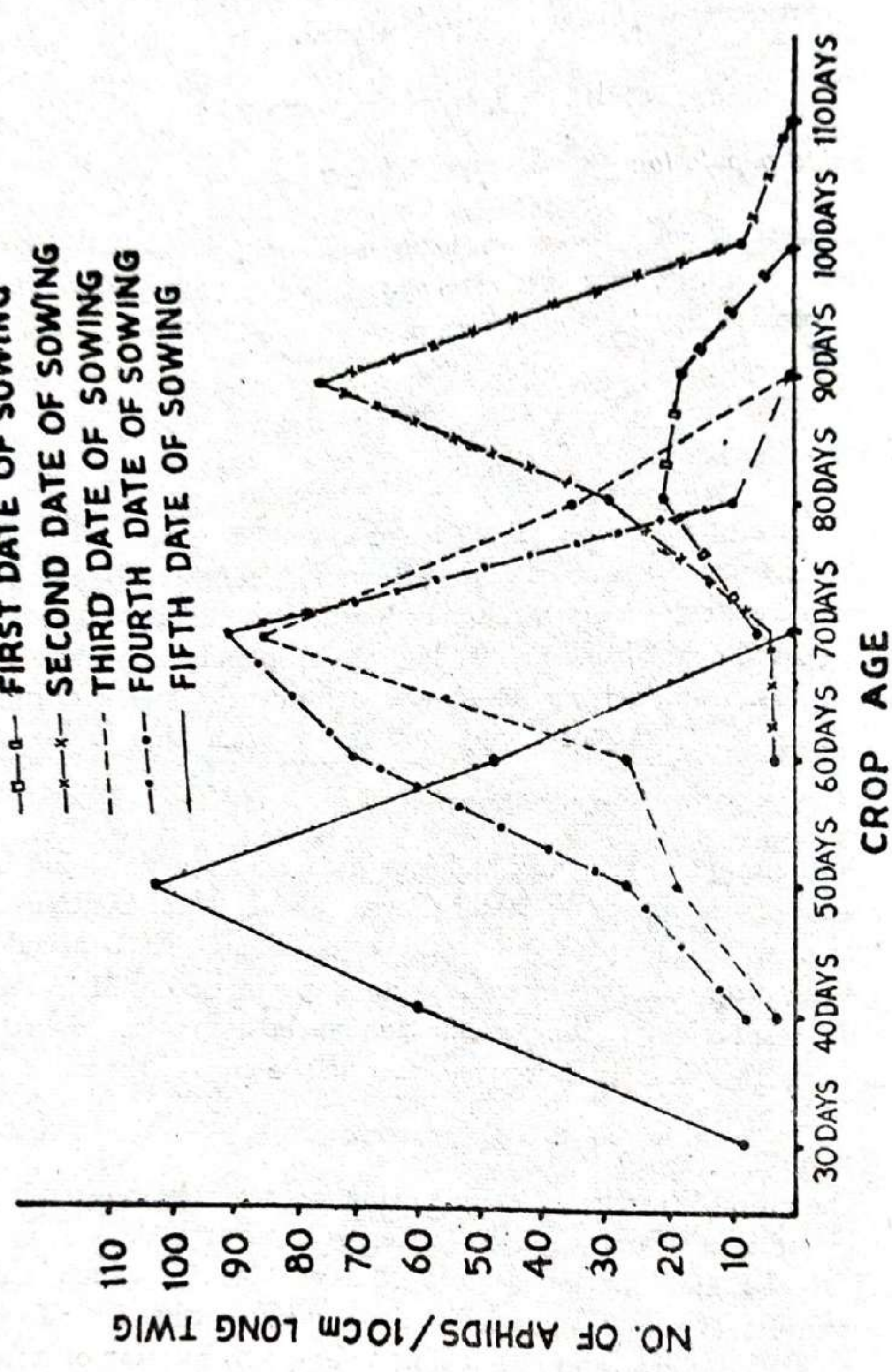

Fig.1 - EFFECT OF DIFFERENT DATES OF SOWING AND AGE OF THE MUSTARD CROP ON THE INCIDENCE OF L. ERYSIMI

The interactions between dates of sowing and fertilizer doses were also not significant. However, the lowest population (12.63 aphids/twig) was observed in the first date of sowing with 60 kg N/ha and maximum population (53.27 aphids/twig) in the fifth date of sowing with 60 kg N+30 kg P+20 kg K/ha.

Effect on grain yield (Table 1, Fig. 2)—

TABLE 1

Effect of dates of sowing and fertilizer combinations on the aphid population (*Lipaphis erysimi*) on grain yield (Mustard—*Brassica juncea* var. *varuna*)

Treatments/ subtreatments	Average number of aphids/10 cm long twig	Average grain yield (Kg/ha)
Date of sowing (Treatments)		
First (25 Sept. 1978)	13 20	121.03 (10.82)
Second (10 Oct. 1978)	24.27	144.02 (11.82)
Third (25 Oct. 1978)	31.56	107.83 (10.16)
Fourth (10 Nov. 1978)	40.23	59.70 (7.55)
Fifth (25 Nov. 1978)	52.02	00.00 (0.71)
S em	2.93	(1.12)
C D at 5%	8.46	(3.23)
Fertilizer combinations (Sub treatments)		
F_1 (60 N + 30 P + 20 kg/ha)	32.28	110.35 (8.32)
F_2 (60 N/ha)	31.82	84.76 (7.34)
F_3 (60 N + 30 P/ha)	32.67	129.32 (8.97)
S em	2.73	(0.71)
C D at 5%	N. S.	(N. S.)

Figures in parentheses converted to $\sqrt{x + 0.5}$

NS = Not significant.

Maximum grain yield (144.02 kg/ha) was obtained in the crop of the second date of sowing. It was, however, at par with the yields of crops of the first and third dates of sowing. The yields of crops of the first and second dates of sowing were significantly more than the yield of the crop of the fourth date of sowing. Crop yields of the third and fourth dates of sowing were at par with each other. No grain yield was obtained from the crop of the fifth date of sowing as the crop died prematurely in the initial flowering stage due to severe aphid infestation. Relatively younger age of mustard crop could therefore be said to be the most vulnerable stage during which aphid infestation causes maximum loss.

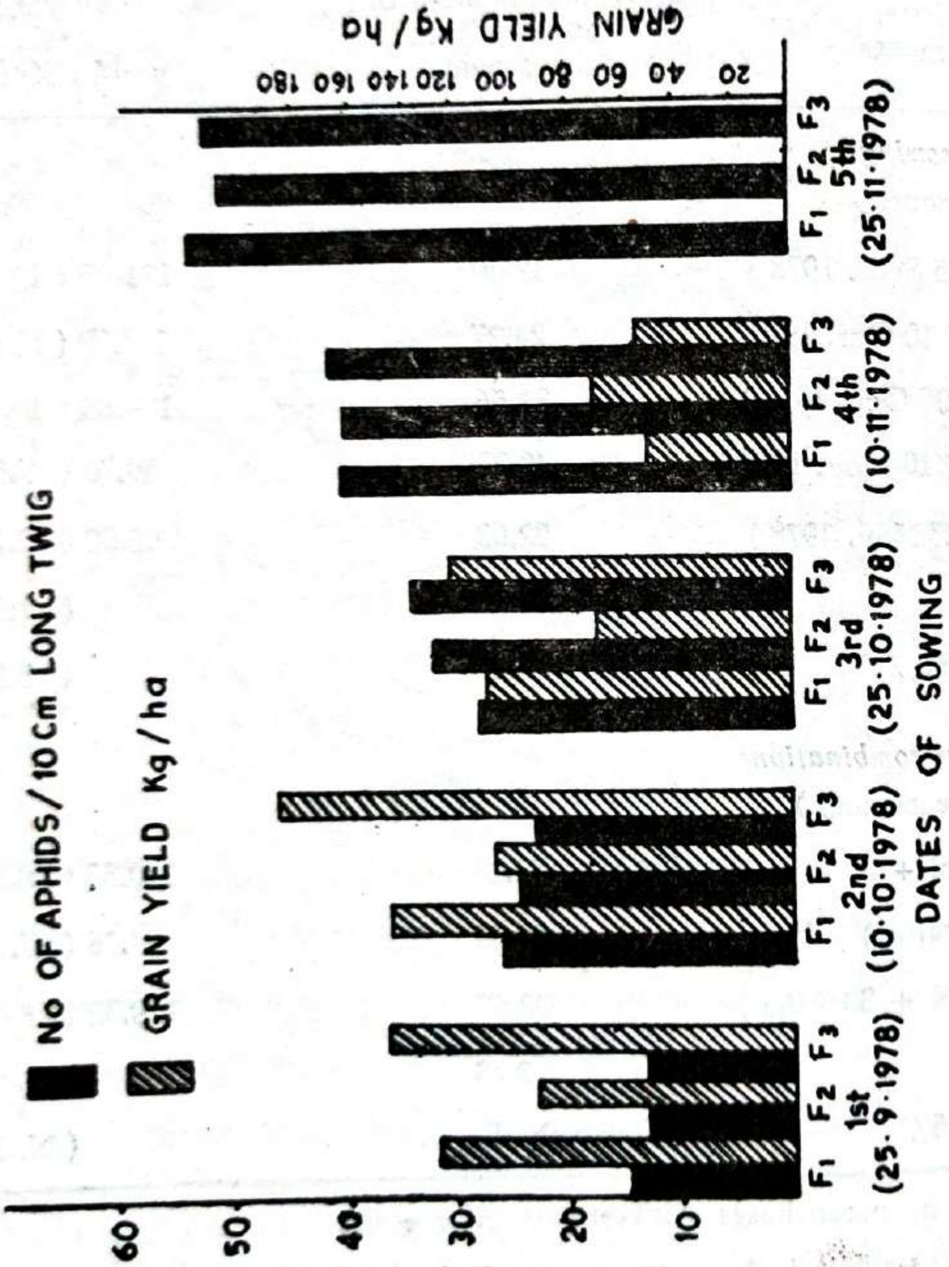

Fig. 2 - EFFECT OF DIFFERENT DATES OF SOWING AND FERTILIZER COMBINATIONS ON THE INCIDENCE OF L. ERYSIMI AND YIELD OF MUSTARD

Fertilizer combinations did not differ significantly from one another. Maximum grain yield (129.32 kg/ha) was recorded in the sub-treatment 60 kg N+30 kg P/ha, followed by the yield in sub-treatment 60 kg N+30 kg P+20 kg N/ha (110.35 kg/ha). The subtreatment 60 kg N/ha recorded the lowest grain yield (84.76 kg/ha).

The interactions between the dates of sowing and fertilizer doses were also not significant. However, the second date of sowing with fertilizer combination of 60 kg N+30 kg P/ha gave the maximum grain yield (182.67 kg/ha), followed by yield in the first date of sowing (145.51 kg/ha) with the same fertilizer combination.

Tripathi and Singh (1964) also found variations in the incidence of mustard aphid and yield of mustard due to sowing date. Early plantings (5th to 20th October) eascaped heavy infestation in the beginning and gave some yield but late plantings (15th Oct. to 20th Nov.) were heavily infested from the early crop stage and gave no yield. Kundu and Pant (1968) found that the multiplication of the mustard aphid was significantly more on 62 and 72 days old mustard plants (initiation of flowering and of pod formation stages) than that on 42, 52 and 82 days old plants. Further, they reported that the grain yield of plants infested on 82 days old plants (half mature pod stage) and afterwards was significantly more than that of plants infested on 72 and 62 days old plants and there was no pod and grain formation in 42 and 52 days old infested plants (seedling and vegetative stages). These findings support the results of the present studies in that the early vegetative stage is the most vulnerable period in the growth of mustard plants when severe aphid infestation leads to total crop failure and this situation develops in late sown (25th Nov.) crop due to migration of aphids which have multiplied on early sown mustard fields. Early sown mustard escapes pest infestation at this vulnerable stage and the incidence of the pest in later stages of growth is also much less.

Regarding the effect of the major plant food elements viz., N, P and K, on the incidence of mustad aphid, there are some conflicting reports of previous workers. Kundu and Pant (1967) found no appreciable effect of these elements on the speed of development, longevity and fecundity of the pest. Makhmoor (1975) reported that the incidence of the pest increased significantly by application of more nitrogen but not by the application of phosphorus and potash. Valunjkar (1976) reported that nitrogen had a positive influence on the fecundity and incidence of the pest but had no significant effect on the speed of development and survival and that phosphorus application (upto 40 kg/ha) had a positive influence on survival. Regarding interaction between N & P, the maximum population was recorded on plants provided with 60 kg N and 60 kg P/ha. In our present studies though the different fertilizer combinations did not differ significantly in the pest incidence and grain yield, the fertilizer combination of 60 kg N+30 kg P/ha proved to be the best.

In conclusion, it can be said that manipulation of date of sowing of mustard and fertilizer levels will not be enough to ward off the pest infestation completely and to secure maximum yield potential but can be an important adjunct to other methods of control viz., chemical and biological, to achieve these ends. Moreover, their integtation with chemical and biotic factors will be much economical by reducing the insecticidal applications from 4-5 to 1-2.

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A NOTE ON THE LEVELS OF APHID (*Myzus persicae* Sulzer) INFESTATION ON THE GROWTH OF CHILLIES (*Capsicum annuum* L.) SEEDLINGS*

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ABSTRACT

The effect of aphid infestation at different levels viz , one, three and five aphids per plant were studied on 25 days old chilli seedlings under glasshouse conditions. Twenty days after inoculation, the shoot and root lenth, fresh and dry weight of the seedlings, number of leaves and total leaf area of the seedlings were recorded. It was found that the initial infestation level of even one aphid per seedling was found to be critical to cause considerable damage with referenee to all parameters observed. The damage was considerably high at higher levels of infestation when compared with control of no infestation

INTRODUCTION

Insect and non-insect pests which feed by sucking the sap from plants can reduce the growth of the plants and this may also result in poor development of roots and later wilting condition especially under drought conditions may arise (Van Emden *et al*., 1969; Dixon, 1971). *Myzus persicae* Sulzer is one of the most destructive species of aphids, colonising almost all parts of some important plants like chillies and tobacco above ground level and infest both seedlings as well as matured crop. The infesation results in the depletion of carbohydrates in tobacco (Baron and and Guthrie, 1960), reduction in plant sap (Forrest *et al*., 1973) and reduction in growth due to an increase in growth inhibiting substances and a decrease in cytokinins, gibberellins and auxins in the radish seedlings (Hussain *et al*., 1973). The critical level of aphid infestation to cause economic damage was worked out earlier by Varma *et al* (1974) and to work out aphid threshold on chillies an experiment was laid out under glasshouse conditions and the results of the experiments are discussed in this paper.

* Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M. Sc. (Ag.) Degree.

MATERIALS AND METHODS

Chilli seedlings were raised in pots in the glasshouse and the inoculations were made on the 25th day after germination. Three levels of infestation were made and the seedlings were inoculated at the rate of one, three and five aphids per seedling, keeping an uninfested control and the experiment was replicated six times. The seedlings were then covered with iron ring cages and the observations were made twenty days after inoculation on the parameters such as (i) shoot length, (ii) root length, (iii) fresh weight of the seedlings, (iv) dry weight of the seedlings, (v) number of leaves per seedling and (vi) total leaf area per seedling.

RESULTS AND DISCUSSION

The extent of damage caused by the aphid at known levels viz., one (low) three (medium) and five (high) levels of infestation were worked out and the results are given in table 1 and figure 1.

Shoot length

Normal uninfested seedlings were 18.77 cm long as against the lengths such as 12.97 cm, 12.04 cm and 11.12 cm for the seedlings infested with low, medium and high levels of aphids respectively. There was no significant difference between high and medium levels and between medium and low levels but there was significant decrease in shoot length in the aphid infested seedlings compared to control.

Root length

Root development was hindered due to aphid attack and it was maximum at high level of infestation (35.04 %) followed by medium and low levels which were at par with each other.

Fresh and dry weight of the seedlings

Significant decrease in both fresh and dry (on oven dry basis at 60°C for 72 h) weight of the seedlings was observed and the maximum reduction in both fresh and dry weight was in the order of high, medium and low levels of infestation.

Number of leaves

The leaf formation was significantly affected by aphid infestation. On an average healthy seedlings had 7.6 leaves as against 6.8, 5.9 and 5.2

leaves at low, medium and high levels of infestation. The leaves were malformed and were underdeveloped.

TABLE 1

Effect of aphid infestation on the growth of chilli seedlings.

Sl. No.	Parameters	Level of infestation per seedling			Control
		5 aphids	3 aphids	1 aphid	
1.	Shoot length in cm	11.12 (40.75)	12.04 (35.85)	12.97 (30.90)	18.77 (—)
2.	Root length in cm	5.32 (35.04)	6.28 (23.32)	6.82 (16.72)	8.19 (—)
3.	Fresh weight of the seedling in gm	1.13 (47.69)	1.37 (36.57)	1.40 (35.19)	2.16 (—)
4.	Dry weight of the seedling in gm	0.19 (44.12)	0.22 (35.27)	0.24 (29.41)	0.32 (—)
5.	Number of leaves per seedling	5.23 (31.00)	5.88 (22.43)	6.75 (10.95)	7.58 (—)
6.	Total leaf area per seedling	23.20 (57.50)	27.29 (50.04)	33.63 (38.39)	54.59 (—)

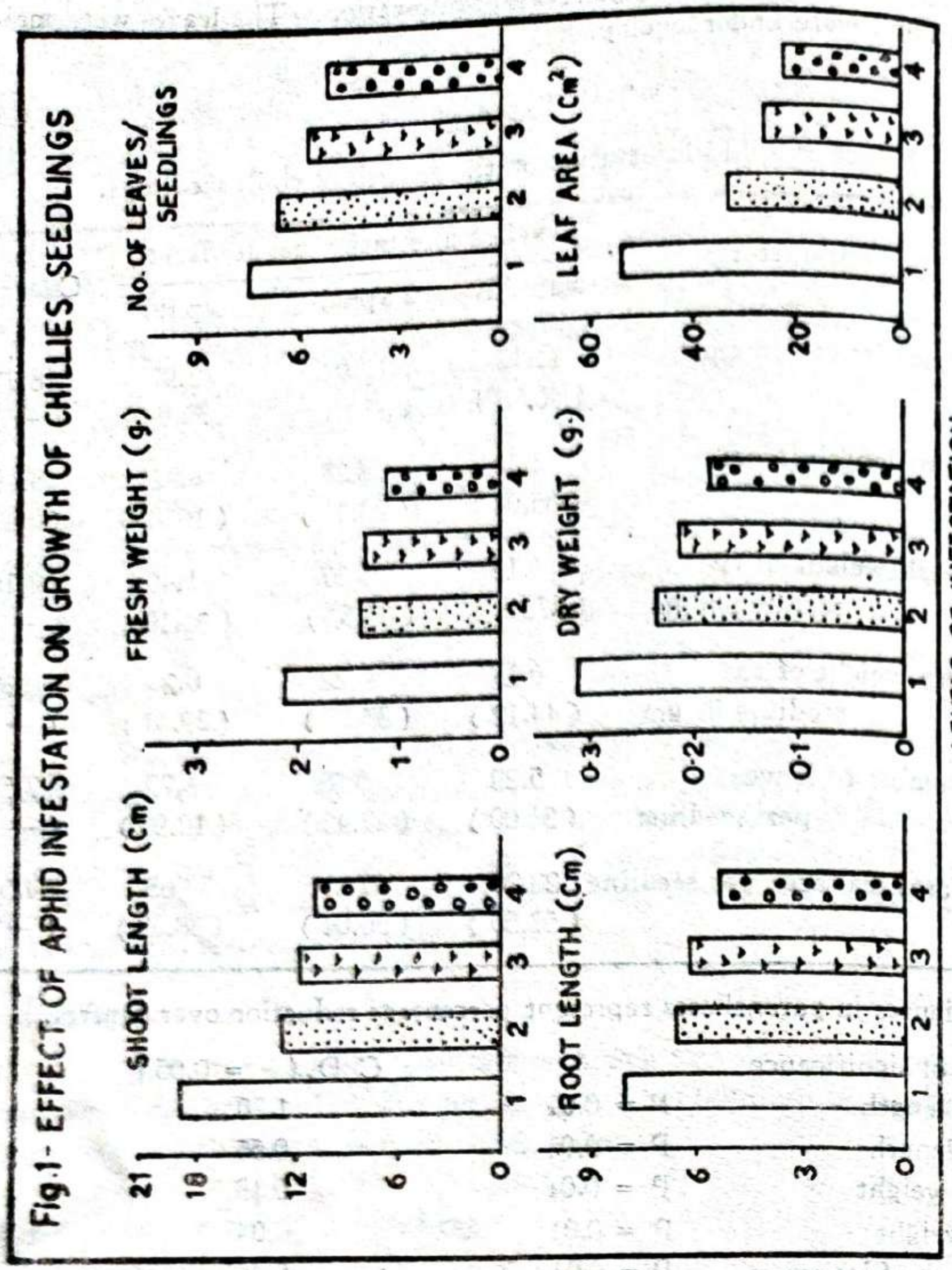
(Figures in parentheses represent percentage reduction over control.)

Level of significance		C D. (P = 0.05)
Shoot length	P = 0.01	1.20
Root length	P = 0.01	0.55
Fresh weight	P = 0.01	0.19
Dry weight	P = 0.01	0.04
Number of leaves	P = 0.01	0.40
Total leaf area	P = 0.01	6.58

Total leaf assimilative area per seedling

Drastic reduction in the leaf assimilative area of the seedlings was noted upto a level of 5.75 per cent. Uninfested seedlings had a leaf area of 54.6 cm^2 as against 33.6, 27.3 and 23.2 cm^2 in the seedlings infested at the rate of one, three and five aphids.

Fig.1- EFFECT OF APHID INFESTATION ON GROWTH OF CHILLIES SEEDLINGS



Levels of aphid infestation : (1) Uninfested control ; (2) One aphid per seedling (3) Three aphids per seedling and (4) 5 aphids per seedling.

Thus on chillies the growth was very much affected by aphid infestation. At high and medium levels the damage was more and there was not much difference between these two treatments whereas, at low levels the damage was much less but always significantly differed from control. This heavy damage at medium and high levels might be due to rapid multiplication of aphid on the small seedlings while it took comparatively longer time for the population build up at low levels. These heavy damages and the reduction in growth might be due to the increase in the growth inhibiting substances and decrease in auxins and gibberellins as observed in radish (Hussain *et al.*, 1973). Besides, due to continuous de-sapping, the developmènt of the leaves was affected which resulted in crinckling and malformation of leaves. This led to the reduction in leaf assimilative area and less photosynthesis, thereby resulting in poor growth of the seedlings. So, though the damage was slow èven the low level of infestation was critical to cause economic damage to the chilli seedlings.

ACKNOWLEDGMENT

The senior author sincerely expresses his gratitude to Tamil Nadu Agricultural University for giving permission to publish his M. Sc. (Ag.) thesis.

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The Aphids : 308-315

STUDIES ON THE TOXIC EFFECT• OF SOME INSECTICIDES ON PARASITES (*Aphelinus mali* Halt. and *Aphidius platensis* Breth.) AND PREDATOR (*Menochilus sexmaculatus* F.) of Chilli aphid, *Myzus persicae* Sulzer

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ABSTRACT

Nine insecticidal treatments were compared with the untreated control to test the toxic influence of insecticides on the hymenopteran parasites ***Aphelinus mali*** and ***Aphidius platensis*** and the coccinellid ***Menochilus sexmaculatus*** predating on ***Myzus persicae*** Sulzer under field conditions. Parasitisation was maximum in the plots treated with fenvalerate (Sumicidin) 0.05 per cent while methamidophos (Monitor) 0.05 per cent was highly toxic. Monocrotophos 0.1 per cent and monocrotophos 0.05 per cent and dichlorvos 0.05 per cent tank mix were not toxic to *A. mali* but prevented the parasitisation by *A. platensis*.

However, fenvalerate 0.05 per cent and methomidophos 0.05 per cent were toxic to both the adults and grubs of the predator *M. sexmaculatus* while dichlorvos 0.05 per cent was found bo be least toxic. At the same time phosalone 0.05 per cent and dimethoate 0.05 per cent were found to be safe against the adult and the grubs, respectively.

INTRODUCTION

In recent years there has been considerable interest in the develop-ment of plant protection programme that assures a more competitive use of chemical and biological methods of pest control. The Integrated Control Programme operates on the principle that certain chemical control measures can destroy the pests effectively while their enemies are spared thereby, subsequent increase in pest population is restricted. The success of the integrated pest control programme depends

• **Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M, Sc. (Ag.) Degree.**

upon the selection of pesticides which are less toxic to the natural enemies than the pests. Hence a knowledge of the pattern of parasite and predator tolerance or susceptibility to the insecticides will help in the development of successful integrated control programmes. Earlier experiments by different workers showed that several contact insecticides and organophosphorus compounds which when applied to control insect pests were toxic to the parasites (Ripper *et al.*, 1950; Bartlett, 1963; Shorey, 1963; Godfrey and Root, 1968; Summer *et al.*, 1975; Delorme 1976 a, b; Iacob and Brincoveanu, 1977) and predators (Way, 1950; Gupta and Kushwaha, 1970; Rangaswamy, 1976) on aphids.

In recent years, the green peach aphid *Myzus persicae* Sulzer has become a meance to the farming community and the use of several insecticides resulted in the development of resistant forms. Under the circumstances, evolution of some integrated control measures will be effective in checking the pest especially under present conditions where natural enemies like *Aphelinus mali* Hald., and *Aphidius platensis* Breth., parasitise *M. persicae* to an extent upto 90 per cent and *Menochilus sexmaculatus* F., which preys on this aphid. Hence a trial was laid out to test the effect of insecticides on the parasite-predator population of *M. persicae* in the treated chilli plants and the results are reported hereunder.

MATERIALS AND METHODS

A field experiment to control the major pest of chillies with nine insecticide treatments (Table 1) and an untreated check was laid out with three replications.

The chemical treatments were given as foliar sprays at 15 days interval starting from one month after planting. The population of the aphids and mummified aphids due to the attack of *A. mali* (black) and *A. platensis* (golden colour .) and the adult and grub population of *M. sexmaculatus* were recorded prior to and ten days after each spraying on five plants from each plot.

RESULTS AND DISCUSSION

Parasites :

Application of insecticides indirectly influenced the parasitisation of both parasites through their action on aphid population (Table 1; Fig. 1). The population of aphid as well as of parasites was maximum

TABLE 1

Effect of certain insecticides on the parasites (*Aphelinus mali* Hald. and *Aphidius platensis* Breth.) and predator (*Menochilus sexmaculatus* F.) complex of the aphid *Myzus persicae* Sulzer.

Sl. No.	Treatment	Population of the aphid	Population of mummies		Population of *Menochilus sexmaculatus*	
			A. mali	*A. platensis*	Adult	Grubs
1.	Dichlorvos 0.05%	399.3	29.3	2.6	2.62	8.67
	(Nuvan 100 EC 0.5 ml/1)	(15.78)	(5.37)	(1.57)	(1.69)	(2.69)
2.	Dimethoate 0.5%	500.3	68.5	2.9	0.88	4.55
	(Rogor 35 EC — 1.5 ml/1)	(17.97)	(7.79)	(1.55)	(1.11)	(1.93)
3.	Fenvalerate 0.05%	1413.7	462.5	47.3	0	0
	(Sumicidin 20 EC — 2.5 ml/1)	(35.13)	(20.02)	(5.37)	(0.71)	(0.71)
4.	Methyl demeton 0.05%	397.7	54.9	6.1	0	0.22
	(Metasystox 25 FC — 2 ml/1)	(16.32)	(6.38)	(2.06)	(0.71)	(0.82)
5.	Methamidophos 0.05%	28.9	1.7	0.1	0	0
	(Monitor 50 EC — 1 ml/1)	(3.99)	(1.42)	(0.77)	(0.71)	(0.71)
6.	Monocrotophos 0.05%	633.7	105.6	4.3	0.88	0.89
	(Nuvacron 40 EC — 1.25 ml/1)	(22.46)	(10.20)	(1.90)	(1.03)	(1.11)
7.	Monocrotophos 0.01%	451.1	67.6	7.1	0.67	0.33
	(Nuvacron 40 EC — 2.5 ml/1)	(19.05)	(7.97)	(2.38)	(0.98)	(0.88)

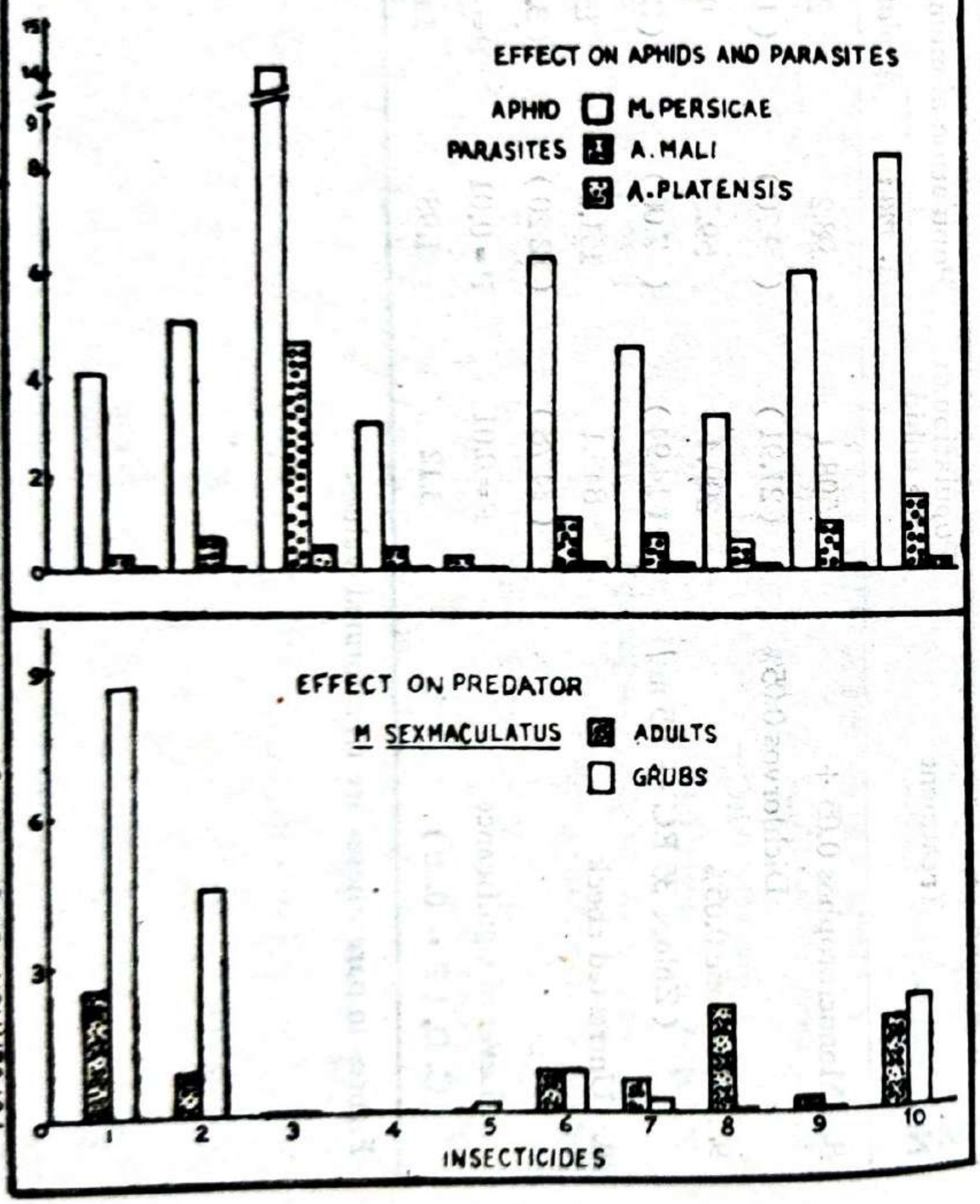
Table 1—(*contd.*)

Sl. No.	Treatment	Population of the aphid	Population of mummies		Population of *Menochilus sexmaculatus*	
			A. mali	*A. platensis*	Adult	Grubs
8.	Monocrotophos 0.05 +	598.1	98.2	2.5	0.33	0.89
	Dichlorvos 0.05%	(21.91)	(9.70)	(1.70)	(0.86)	(1.05)
9.	Phosalone 0.05%	309.4	59.3	9.1	2.22	1.11
	(Zolone 35 EC — 1.5 ml/l)	(14.94)	(7.00)	(2.69)	(1.38)	(1.16)
10.	Untreated check	843.1	151.9	15.1	1.88	2.33
		(24.78)	(12.20)	(3.70)	(1.42)	(1.53)
	Level of significance	P = 0.01	P = 0.01	P = 0.05	P = 0.01	P = 0.01
	C. D. (P = 0.05)	3.12	1.98	1.68	0.38	0.50

Figures in parentheses are transformed values.

in the plots treated with fenvalerate which showed that fenvelerate is neither toxic to the aphid nor to the parasites. Though in the other treatments, the aphid population was considerably reduced than in the untreated check, the population of *A. mali* was higher in monocrotophos (0.05) and monocrotophos-dichlorvos mixture treated plots, recording a fairly higher population of parasitised mummies which revealed that these organo-phosphorus compounds had minimum effect on the establishment of *A. mali* under field conditions. In contrast, monitor was highly toxic to both the aphid and *A. mali* and did not allow the parasite to establish under field conditions and this was followed by dichlorvos, methyl dimeton and phosalone.

Fig 1 - EFFECT OF CERTAIN INSECTICIDES ON NATURAL ENEMY COMPLEX OF APHID



Though higher per cent parasitisation by *A. platensis* was recorded under glass house conditions by Easwaramoorthy *et al.* (1976), the parasitisation was low under field conditions and it might have been due to competitive nature of *A. mali* compared to *A. platensis.* However, in this case also fenvalerate recorded the maximum population of *A. platensis* and the minimum in monitor treated plots. All other chemicals also significantly reduced parasitisation than in no treatment and fenvalerate treated plots. Though fenvalerate is the least toxic chemical to both the parasites it cannot be used under conditions when the aphid population needs to be kept below the threshold level. Under such circumstances monocrotophos 0.05 per cent is effective against the aphid and at the same time it is fairly safe to the parasites. This might be due to the failure of these chemicals to penetrate the mummies and kill them (Shorey, 1963; Godfrey and Root, 1968).

Predator :

Though dichlorvos was toxic to the parasites, it was found safe against the predator *M. sexmaculatus*. Both the populations of adults and grubs were high in the dichlorvos treated plots while fenvelerate which was found safe against the parasites was highly toxic to the predator and recorded no occurrence of both adults and grubs. Monitor which was highly toxic to the parasites was also toxic to the predator along with methyl demeton and monocrotophos and these treatments were on par with the other treatments except dichlorvos and the control.

Though Gupta and Kushwaha (1970) reported the toxic nature of dichlorvos to the predators, it was found to be least toxic to *M. sexmaculatus* under field conditions which might be due to lesser persistance of this chemical. However, the present findings confirm the results obtained by Rangaswamy (1976) who reported the toxicity of monocrotophos to the predators.

Fenvalerate which was reported to be only partially effective against *M. persicae* by Abdul Kareem *et al.* (1977) recorded higher population of parasites in our experiments which might be due to the reason that the aphids left out after treatment were sufficient for the survival and build up of the parasites. However, fenvalerate did not favour the establishment of the predators due to its direct contact toxicity over the adults and grubs of the predator whereas, dichlorvos which was toxic to the parasites was found to be safe against the predator. Hence an integrated control programme of the aphid and other pests should be aimed at keeping the population of parasites and predators undisturbed.

ACKNOWLEDGMENT

The senior author expresses his gratitute to Tamil Nadu Agricultural University for giving permission to publish his M. Sc. (Ag.) thesis.

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The Aphids : 316-319

RICE ROOT APHIDS AND THEIR CONTROL

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ABSTRACT

The most commonly occurring rice root aphid is *Rhopalosiphum rufiabdominalis* (Sasaki) which occurs during November — February. Carbofuran @ 1.0 Kg. a. i. / ha effectively controls the pest.

INTRODUCTION

The first report on the occurrence of rice root aphid was by Tan (1924) who recorded the incidence of *Dryopeta hirsuta* Baker from the Philippines. Subsequently, incidence of *Tetraneura nigriabdominalis* (Sasaki) (Syn. *T. hirsuta* B.) was reported by Suenaga (1952), and Israel and Rao (1955) from Japan and India respectively. Recently, Dani and Majumdar (1978) reported the occurrence of two more species of rice root aphids viz., *Rhopalosiphum rufiabdominalis* (Sasaki) and *Geoica lucifuga* (Zhentner) from India.

Though the root aphids have not yet assumed the status of serious pests of rice, of late, *Rabi* nursery beds were observed to be colonised commonly by a complex of root aphids. Little is known about the rice cultivars usually infested by these hitherto insignificant pests of rice. Such information is perhaps an essential prerequisite for developing a pest management programme in rice cultivation. It was therefore thought appropriate to obtain firsthand information on the occurrence, abundance, composition, distribution and control of aphids infesting different rice cultivars in the Institute farm.

METHOD OF STUDY

RESULTS AND DISCUSSION

A preliminary survey of rice root aphids was conducted during 1975-77 and it was observed that the *Rabi* nursery beds were commonly colonised by *T. nigriabdominalis*, *R. rufiabdominalis* and *G. lucifuga*. Infestation by root aphids leads to stunting and yellowing of the leaves

TABLE 1

Incidence and composition of root aphids in different rice cultivars.

Name of rice cultivars	Root aphids involved		
	T. nigriabdominalis	*R. rufiabdominalis*	*G. lucifuga*
Jaya	+ + +	+ +	+
CR-139-1047	+ +	+ +	–
Sona	+	+	–
BJ—1	+	+ +	+
IR—8	+ +	+ +	–
IR 26	+ +	+ +	+
TN—1	+	+ +	–
CR—123—22	+	+	–
RP—79—5	+	+ +	–
CR—141—233	+ +	+	–
T—657	Nil	+ +	+
JS—52—102	+ +	+ +	–
Bala × JBS—508 (7)	+	+	–
MW—10	+ +	+	–
FH—575	+	+ +	–
FH—125	+	+	–
IET—1444	Nil	+ +	–
IET—2662	Nil	+ +	–
IURON—128	+ +	+	–
MTU—17—M4	+	+ +	–
IET—2473	+	+	–
A 514 × Ratna—K1	+	+ +	+
CR—196—36	+ +	+	+
CR—113—84—2	+	+	–
AxR—528	Nil	+ +	–
CR—141—191	+ +	+ +	–
Jhona—349	+	+	–
Ratna	+ +	+ +	+

+ + + = above 70%
+ + = around 5 %
+ = below 10 %

of rice seedlings. In case of serious infestation, the plants sometimes did not recover even after transplanting. Among the root aphids involved. *R. rufiabdominalis* was observed to be the most commonly occurring species infesting all the rice cultivars under observation during November-February. *T. nigriabdominalis* ranked second in order of rice cultivars infested, while *G. lucifuga* was only occasional in its incidence (Table 1).

Population of all the three species of aphids were predominantly nymphal throughout the season. The migrants (alatae) were observed only as founders of the colonies during the sowing season (November-January) and also during February-March when most of the transplanting of rice seedlings were over. Table 1 clearly reveals that amount the three different species of root aphids which normally occur in the Institute farm, only *R. rufiabdominalis* was found to be distributed nearly randomly and was found to be distinctly aggregated. It may also be seen that out of 28 rice cultivars infested by different species of root aphids, Jaya was infested predominantly by *T. nigriabdominalis*.

TABLE 2

Effect of granular applications on rice root aphid complex.

Treatment on 15 DAS		Initial population on 15th DAS*	No. of aphids/hill at	
			20 DAS	25 DAS
Diazinon	0.5	128.6	53.3	21.3
	1.0	131.3	51.2	17.3
	1.5	133.7	44.3	15.2
Carbofuran	0.5	121.3	23.2	3.1
	1.0	118.2	19.0	—
	1.5	123 6	11.3	—
Quinalphos	0.5	125.3	69.2	21.1
	1.0	137.4	51.6	18.2
	1.5	135.6	48.2	12.4
Sevidol	0.5	122.3	35.2	7.6
	1.0	119.9	31.6	3.4
	1.5	128.4	21.2	2.1
Cytrolane	0.5	130.0	52.8	11.2
	1.0	132.4	49.3	12.3
	1.5	128.4	41.2	7.6
Control		134.0	234.3	369.2

*Days after sowing

Five granular formulations of insecticides viz., diazinon, quinalphos, carbofuran, phorate and cytrolane were tested as candidate compounds for use against these pests. The experiment was conducted in 1 × 1 mt micoplots arranged in randomised block design. The results of the investigations are summarised in Table 2.

The results indicate that only carbofuran at the rate of 1 kg a. i./ha was effective in eliminating the population of rice root aphids.

ACKNOWLEDGMENT

Thanks are due to Dr. H. K. Pande, Director, Central Rice Research Institute, Cuttack and Dr. K. C. Mathur, Head of Entomology Division for providing necessary facilities and their keen interest in the present investigetion.

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The Aphids : 320-325

CONTROL MEASURES AGAINST *RHOPALOSIPHUM MAIDIS* (FITCH) INFESTING BARLEY

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ABSTRACT

Rhopalosiphum maidis (Fitch) is a serious pest of barley in India. Field trials on its chemical and cultural control were conducted at the Indian Agricultural Research Institute, New Delhi. Insecticide granules viz., phorate 10 %, disulfoton 5 %, mephospholan 5% and carbofuran 3 % (0.5 and 1.0 kg a.i./ha) gave effective control when applied either in seed furrow at sowing or as broadcast on young plants on aphid appearance. The treatments resulted in increased grain yield from 5.13 to 14.78 Q/ha. In a preliminary trial, seed treatment with carbofuran (5 parts a.i. with 100 parts of seed) was also seen to be quite effective.

An early spray of methyl parathion, fenitrothion or endosulfan (0.05 %) at the rate of 1000 litres/ha was effective to protect the crop throughout the season and it was as good as two sprays, one early and the other late, and was superior to late spray. Among the several dust formulations tested viz., BHC 5 %, BHC 10 %, carbaryl 5 %, malathion 5 % and parathion 2 % at the rate of 25 kg/ha, parathion 2 % were the best followed by malathion 5 %.

Studies on aphid incidence showed that early and timely sowing of crop is useful in saving the crop from heavy aphid attack. Cultivation of aphid resistant varieties is recommended. Variety DI-117 was found to be resistant among the various varieties tested.

INTRODUCTION

The corn leaf aphid *Rhopalosiphum maidis* (Fitch) is a serious pest of barley crop. It sucks the sap from leaves as a result of which they turn yellow and ultimately dry. The infested plants remain stunted in growth. In case of severe injury, the main shoot dries up resulting in the production of late tillers bearing ear heads devoid of grains. The losses in grain yield have been found to vary from 3 to 68 per cent in some promising and commercial varieties. The pest also causes appreciable decrease in fodder yield varying from 7 to 43 per cent (Bhatia and Singh, 1977). Some genotypes are highly susceptible and losses in grain yield may be to the extent of 100 per cent (Murthy *et al.*, 1968). Field trials for evolving suitable control measures against the aphid were carried out at the Indian Agricultural Research Institute, New Delhi and the findings are presented in this article.

ANALYSIS OF RESULTS AND RECOMMENDATIONS

A. *Chemical control*

Insecticides applied as granules, seed treatment, as spray and dusts were evaluated. These trials were conducted with a view to refining the control measures with regard to dosage and time of application. The farmer thus has a choice of the control measures and depending upon the intensity of the pest and the available resources can apply any of them to control the aphid.

(1) *Granule application*

Four systemic insecticides viz., disulfoton 5 %, phorate 10 %, mephospholan 5 % and carbofuran 3 % were tested. These granules were applied in seed furrow at the rate of 2 kg and 1 kg a.i./ha. The results showed that each of the insecticides is effective in controlling the pest and results in increased grain yield from 22 to 26 % (Bhatia *et al.*, 1973). These granular formulations were also tested as broadcast in standing crop at the time of aphid appearance and in seed furrow at sowing (Singh and Bhatia, 1976a). Granules were applied at the rate of 1.0 kg and 0.5 kg a.i./ha followed by an irrigation. These treatments also gave effective control of the aphid even at the lower rate and produced 5.13 to 14.78 Q/ha higher grain.

The grain samples from 1.0 kg and 0.5 kg a.i./ha treatments were analysed for the phorate, disulfoton, mephospholan and carbofuran residue and were found to be free.

(2) *Seed treatment*

A preliminary trial was conducted to evaluate the effectiveness of seed treatment with carbofuran and isofenphos during 1978-79. Five parts of actual insecticides (carbofuran, 50 SP and isofenphos 40 % seed dressing) were mixed with 100 parts of seed using gum acacia as adhesive.

Results showed that carbofuran was effective upto ten weeks and gave complete protection against the aphid throughout the crop season. However, isofenphos was not found to be as good as carbofuran.

(3) *Spraying and dusting*

Spray formulations of several systemic and other insecticides were tested during 1969-70 and 1970-71 (Bhatia *et al.*, 1973). It was found that foliar sprays of methyl parathion 0.05 %, fenitrothion 0.05 %, endosulfan 0.05 %, methyl demeton 0.02 %, lindane 0.03 %, diazinon 0.03 %, dimethoate 0.02 %, malathion 0.14 %, and phosphamidon 0.02 % at the rate of 1000 litres/ha effectively reduced the aphid population and produced 14 to 27 % higher grain.

It has been generally observed that cultivators resort to spraying when plants are fully covered with aphids. Therefore, with a view to finding out the suitable time and number of spray applications, field trials were conducted for 4 years from 1971-72 to 1974-75 with methyl parathion, fenitrothion and endosulfan (0.05 %) as foliar sprays at the rate of 1000 litres/ha (Singh and Bhatia, 1976 b). The sprays were applied (i) at the time aphids appeared on the crop (ii) when aphid infestation was at its peak, and (iii) once at the time of appearance and another when the aphids were at the peak. Results revealed that an early spray of insecticides was effective to protect the crop throughout the season and it was as good as two sprays, one early and the other late, and was superior to late spray. Furthermore, two weeks delay in spraying of methyl parathion, fenitrothion and endosulfan resulted in grain loss to the extent of 4 Q/ha. Therefore, first spray should be done at the appearance of aphid colonies and if necessary second spraying can be given two weeks after the first spray.

Grain samples were analysed for toxic residue of methyl parathion and fenitrothion and were found to be free from residues.

Experiments were aslo conducted for three years from 1972-73 to 1974-75 with insecticidal dusts. BHC 5 %, BHC 10 %, malathion 5 %, carbaryl 5 % and parathion 2 % were used at the rate of 25 kg/ha. It was observed that parathion 2 % dust was best followed by malathion 5 per cent. Crop protection by these dust formulations resulted in increased grain yield of 21.43 and 17.03 Q/ha, respectively over the untreated check (Singh and Bhatia, 197ob).

B. ***Cultural control***

(1) Sowing time

By changing or carefully selecting the sowing time a particular pest attack can be avoided or reduced considerably. Singh (1979) reported that aphid population on barley starts decreasing rapidly with the earhead emergence in plants (Table 2). Therefore, aphid attack on barley could be considerably avoided if the sowing time is adjusted in such a way that plants start flowering before peak period of aphid infestation. Under Delhi conditions aphid population reaches its peak around the 4th week of February. It has been observed that crop sown by middle of November comes to flowering stage before peak of aphid infestation and thus escapes heavy aphid attack. Therefore, barley sowing around Delhi by middle of November is recommended to avoid the use of insecticidal spraying for aphid control. It has been observed that late sown crop i. e., crop sown after the second week of November suffers considerably from aphid attack and hence would require control measures.

TABLE 1

Incidence of *Rhopalosiphum maidis* on barley variety Ratna at Delhi.

Date of sowing	Av. No. of aphid per shoot on different dates					
	22-1-75	3-2-75	15-2-75	24-2-75	7-3-75	18-3-75
15th October, 74	14.3 (50%)	7.2 (100%)	5.0	2.7	0.0	0.0
31st October, 74	16.1	32.5 (5%)	20.6 (100%)	7.5	0.0	0.0
15th Nov., 74	6.5	16.8	12.1 (90%)	4.0 (100%)	0.0	0.0
30th Nov., 74	3.1	9.2	33.6	21.2 (5%)	2.5 (100%)	0.0
16th Dec., 74	0.0	8.3	30.0	48.8	35.3 (5%)	0.0
31st Dec., 74	0.0	2.4	16.8	40.7	106.2	0.0
16th January, 75	0.0	0.0	11.8	18.5	52.9	0.0

Note :— Figures in parenthesis are percentage of earhead emergence in plants.

TABLE 2

Mean aphid population (*Rhopalosiphum maidis*) on 14 varieties of barley (unprotected) and grain and straw yield in protected and unprotected plots during 1974-75 at Delhi.

Variety	Average number of aphid per shoot on March 4, 1975	Grain yield (Q/ha)			Fodder yield (Q/ha)		
		Prot.	Unprot.	Percent loss	Prot.	Unprot.	Percent loss
Ratna	89.73	35.16	22.53	37.7	45.69	28.49	37.7
Jyoti	96.75	40.42	18.33	54.7	47.73	27.16	43.1
DL 3	110.25	41.18	26.07	36.7	49.11	35.18	28.4
DL 69	96.86	40.60	15.80	61.1	38.29	21.82	43.0
RD 31	64.10	42.31	25.69	39.3	49.31	29.80	39.6
BG 25	85.46	39.22	24.22	38.3	35.73	26 22	26.6
BG 108	94.73	49.64	16.16	67.5	56.20	33.16	41.0
RD 102	99.73	38.93	20.56	47.2	43.42	27.89	35.8
RD 118	56.80	44.31	24.84	43.9	51.09	33.38	34.7
DL 36	45.96	41.36	30.78	25.6	45.98	40.91	11.0
K 125	142.66	38.13	26.64	30.1	53.64	37.89	29.4
RD 57	55.73	37.00	21.87	40.9	47.64	32.31	32.2
RS 6	51.60	33.00	26.36	20.1	52.18	37.73	27.7
DL 117	7.66	47.96	46.60	2.8	48.64	45.38	6.7

Interaction

S. Em $\pm$ 2.47

C. D. 5 % 7.13

Note :— (i) Date of sowing 21-12-74; (ii) No. of irrigations 5;
(iii) Date of spraying :
1st—13-2-'75, 2nd—26-2-'75, 3rd—14-3-'75.

(2) *Use af resistant varieties*

Using variety EB 921 as source of aphid resistance some high yielding varieties of barley have been developed at the Indian Agricultural Research Institute, New Delhi. These varieties have shown aphid resistance of high order and could be profitably utilized against aphid damage. An experiment to assess the losses caused by *R. maidis* to 14 promising varieties of barley conducted by Bhatia and Singh (1977) at new Delhi in 1974-75 showed that the aphid population varied widely among the varieties; the lowest and the highest population per shoot was recorded on variety DL 117 and K 125, respectively (Table 2). The results showed that DL 117 was resistant to the aphid and gave maximum yield of 48 Q/ha. Percentage reduction in grain yield varied between 2 8 in DL 117 and 67.5 in BG 108 The reduction in grain yield was primarily due to reduction in the size and the number of ear heads while the grain boldness remained unaffected.

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ROLE OF FORMULATION IN DETERMINING APHICIDAL EFFICACY OF INSECTICIDAL GRANULES

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ABSTRACT

Among conventional solid and liquid formulations, the granular formulation of insecticides, by virtue of sustained release possesses relatively most persistent aphicical properties. However, the desired efficacy of a particular toxicant granule is greatly dependent on the nature of its formulation incorporating the toxicant, the granular carrier and other adjutants. The residual action of organic insecticides against various aphid pests infesting mustard, pea, okra and cabbage was modified by the inorganic mineral carrier, the binder, the deactivator and the method of formulation. The yield of mustard seed and the insecticidal residue therein were also accordingly affected.

Higher concentration of insecticide in certain granular formulations proved less effective against aphids infesting cabbage, as compared to corresponding formulations with lower concentration. The results highlight a judicious use of insecticides incorporating suitable carriers and other pre-requisites in a granular formulation for maximum aphicidal efficacy, superior yield and minimum insecticidal residue.

INTRODUCTION

Formulation plays a vital role in the ultimate functioning of a toxicant and successful pest control programme. The aphicidal action of a particular insecticide may vary widely, depending upon the efficacy of its particular formulation. A relatively potent aphicide may be rendered less effective by incompatible components in a formulated product. The residual aphicidal effect is also influenced by the type of solid or liquid formulation, viz., wettable powder, granule and emulsion concentrate. The granular formulation by virtue of its release characteristics provides a longer residual action as compared to conventional aphicidal sprays.

Thus, an emulsion spray of lindane gave an LT 50 value of 3.5 days against mustard aphid (Verma, 1979), whereas, its granular formulation enhanced the value to 27.14 days (Nakat, 1970). The granules of disulfoton and phorate persisted for 109.00 and 99.33 days, respectively, against the same pest (Nakat, 1970) and against cotton aphid for 9 weeks (Navaneethan, 1971). Similarly, endosulfan spray against mustard aphid gave an LT 50 value of 4.6 — 5.5 days (Verma, 1979), while the granular formulation persisted for over a month (Sircar *et al.*, 1979). Even the emulsion formulation of systemic insecticides, dimethoate and phosphamidon remained effective against mustard aphid for 15 days (Verma, 1979), whereas in the form of granules, aphicidal efficacy could be observed even up to 74 and 47 days respectively (Sarup *et al.*, 1971). The granular formulation of endosulfan was found to be significantly more effective than endosulfan spray against *Lipaphis erysimi* infesting cabbage up to a period of 30 days (Sircar *et al.*, 1979). Against bean aphid, the granular formulation of phorate, disulfoton and lindane remained effective up to 75 days (Sarup *et al.*, 1974), a residual aphicidal action which no other conventional formulation could achieve. Even the residual action of a particular insecticidal formulation, viz., granule, may vary widely, depending upon the components of formulation. The formulated granules of dimethoate and aphidan on attapulgite carrier were found to retain their efficacy against mustard aphid even after a period of 36 days, as compared to their corresponding proprietary formulations, which were found ineffective. The formulated granules of dimethoate on plain attapulgite persisted even up to 74 days as against its corresponding deactivated formulation found ineffective (Sarup *et al.*, 1971). It was reported by Graham-Bryce *et al.*, (1972) that the granular formulations of phorate and disystor were more effective on pumice than on fuller's earth against the black bean aphid, *Aphis fabae*. The granules of lindane formulated in the laboratory persisted for 75 days against the bean aphid, *Aphis craccivora* as compared to the proprietary product which lasted for 60 days (Sarup *et al.*, 1974).

The intensity of damage, inflicted by important aphid species on agricultural crops resulting in negligible yield, necessitated exploitation of the variations observed in aphicidal efficacy of different granular formulations to select the most suitable formulation. The investigations carried out provide relevent information to indicate vast potentialities of formulation studies for determining persistent aphicidal action of insecticidal granules.

MATERIALS AND METHODS

Insecticides belonging to different groups, viz., chlorinated hydrocarbons, organophosphates and carbamates were variously formulated in the laboratory as five per cent granules on inorganic mineral carriers by surface coating and impregnation methods, incorporating different binders, deactivators, and benzene as a solvent (Sircar, 1976). The formulated granules along with their corresponding proprietary products were evaluated under field conditions as soil and foliar treatment against different species viż., mustard aphid *Lipaphis erysimi* (Kalt.) infesting mustard and cabbage, bean aphid *Aphis craccivora* Koch, infesting pea and cottom aphid *Aphis gossypii* Glover infesting okra (ladies finger) crop. The experiments were laid out in a randomised block design with four applications of each treatment. Periodical observations on aphid population following granular treatment were recorded and the data subjected to analysis of variance (Snedecor and Cochran, 1968).

The materials used for formulation studies and the abbreviations used in the text are :

(1) *Insectidides*—BHC, lindane and endosulfan (chlorinated hydrocarbons); dimethoate, aphidan, monocrotophos, phosphamidon, phorate and disulfoton (organophosphotes); carbofuran and aldicarb (carbamates).

(2) *Carriers*—Attapulgite (Atta), bentonite (Bento.) fuller's earth (F. E.). kaolinite (Kao), Chinaclay (Ch clay), diatomite (Diato.), magnesite (Mag.), gypsum (Gyp.), talc (Talc.), pyrophyllite (Pyro.), dolomite (Dolo.), and quartz (Qtz.).

(3) *Rinders*—Gum Acacia (G. A.), methyl cellulose (Cel.) gelatine (Ge.) and sodium silicate (S. Sil.).

(4) *Deactivator*—Hexamethylenetetramine (HMT).

(5) *Method of formulation*—Impregnated (Imp.), and surface coated (Sc.).

RESULTS AND DISCUSSION

The results obtained with the granular formulations of different insecticides are discussed in relation to individual aphid species.

(i) *Evaluation of aphicidal efficacy against* Aphis craccivora *Koch., infesting pea crop*

The formulated granules of different insecticides, based on HMT deactivated (D) and plain (P) attapulgite, and prepared by surface coating, were evaluated along with their corresponding proprietary granules as soil treatment before sowing. It is evident from Table 1 that 45 days after granular application, proprietary granules of lindane, phorate, disulfoton, dimethoate and aphidan resulted in significantly low aphid population as compared to their corresponding formulated granules of lindane (D), phorate (P), disulfoton (D & P), dimethoate (D & P), and aphidan (D & P) respectively (Sarup *et al.*, 1974). The plain formulated granules of phosphamidon were superior to the deactivated granules. All the formulations except lindane (D) and phosphamidon (D) were significantly effective against the aphid population as compared to control up to 60 days after soil treatment. The effective aphicidal formulations 75 days after treatment were formulated granules of lindane (P), phorate (D & P), disulfoton (D & P), dimethoate (P), aphidan (D & P) and proprietary granules of phorate, disulfoton, aldicarb and carbofuran. The formulated granules of lindane (P), dimethoate (P) and aphidan (D & P) were thus more effective than their corresponding proprietary products. The only effective aphicidal formulation during the final observation 80 days after treatment, were found to be phorate (D), disulfoton (D & P) and proprietary phorate, disulfoton, aldicarb and carbofuran, with no significant difference among themselves. The plots treated with granules of monocrotophos, found to be relatively an ineffective aphicide, maintained significantly high population of the aphid predator, *Coccinella septempunctata* as compared to rest of the treatments. However, considering the aphicidal action and efficacy against pea leaf miner, only the formulated granules of disulfoton (P) could be considered as most effective among the various formulations tested.

(ii) *Evaluation of aphicidal efficacy against* Lipaphis erysimi *Kalt., mustard crop*

Perliminary investigations against the mustard aphid showed that proprietary granules of disulfoton, phorate, aldicarb, carbofuran and aphidan gave significant reduction in aphid population whereas, dimethoate, lindane and monocrotophos were practically ineffective (Table 2). Amongst the formulated granules, phorate and disulfoton irrespective of deactivation were found effective. The plain granules of dimethoate

TABLE 1 @

Average population of *Aphis craccivora* and *Coccinella septempunctata* at different intervals after soil application of various formulations of insecticidal granules.

Formulation		Average population + of *A. craccivora* after (days) 45	60	75	80	Average population of *C. septempunctata* after (days) 75
Formulated -						
Lindane	D	2.5159 [33.33]	2.9954 [103.33]	2.2378 [50.00]	2.2373 [50.00]	1.1003 [0.33]
	P	2.1659* [15.00]	2.7349** [65.00]	1.7485* [8.33]	2.4358 [100.00]	1.1003 [0.33]
Phorate	D	1.7849** [10.00]	2.3531** [21.67]	1.0000** [0.00]	1.0000* [0.00]	1.0000 [0.00]
	P	2.0966** [11.67]	2.2828** [18.33]	1.4407* [6.67]	1.6681 [33.33]	1.1003 [0.33]
Disulfoton	D	2.1718* [16.67]	2.6362** [46.67]	1.4407* [6.67]	1.4971* [10.00]	1.2594 [1.00]
	P	1.9537** [8.33]	2.1015** [13.33]	1.0000** [0.00]	1.0000* [0.00]	1.0000 [0.00]
Phosphamidon	D	2.6464 [53.33]	3.0946 [125.00]	2.6760 [46.67]	1.6681 [33.33]	1.1590 [0.67]
	P	1.9943** [20.00]	2.8647* [180.00]	2.6060 [50.00]	2.1652 [43.33]	1.0000 [0.00]
Dimethoate	D	2.3219* [23.33]	2.7753** [68.33]	1.9124 [15.00]	1.7263 [50.00]	1.0000 [0.00]
	P	2.0956** [11.67]	2.3531** [21.67]	1.0000** [0.00]	2.0159 [21.67]	1.1590 [0.67]
Aphidan	D	2.2850* [20.00]	2.5469** [35.00]	1.6065* [5.00]	1.5692 [16.67]	1.1003 [0.33]
	P	1.9783** [20.00]	2.7090** [58.33]	1.5376* [14.33]	2.6780 [56.67]	1.0000 [0.00]
Control		2.9225 [91.67]	3.3204 [233.33]	2.8544 [73.33]	2.8642 [75.00]	1.5775* [3.00]

Table 1—(*contd.*)

Formulation	Average popultion + of *A. craccivora* after (days)				Average population of *C. septempunctata* after (days)
	45	60	75	80	75
Proprietary					
Lindane	1.9201** [8.67]	2.8963* [83.33]	3.3357 [250.00]	3.0635 [150.00]	1.2007 [0.67]
Phorate	1.4377** [2.33]	2.0782** [13.33]	1.4407* [6.67]	1.4407* [6.67]	1.0000 [0.00]
Disulfoton	1.1003** [0.33]	1.6065** [5.00]	1.5692* [16.67]	1.0000* [0.00]	1.1003 [0.33]
Dimethoate	1.1590** [0.67]	2.6128** [40.00]	2.9098 [190.00]	2.0663 [26.67]	1.1003 [0.33]
Aphidan	1.0000** [0.00]	2.5064** [31.67]	2.1068 [30.00]	1.5692 [16.67]	1.0000 [0.00]
Monocrotophos	1.0000** [0.00]	2.8065** [66.67]	3.2204 [166.67]	2.7749 [63.33]	1.3597* [2.00]
Aldicarb	1.0000** [0.00]	2.3138** [20.00]	1.4014* [5.00]	1.0000* [0.00]	1.0000 [0.00]
Carbofuran	1.0000** [0.00]	1.9595** [10.00]	1.4718* [8.33]	1.0000* [0.00]	1.1003 [0.33]
'F' test	H.S.	H.S.	H.S.	Significant	Sign
S. Em ±	0.2080	0.1300	0.3860	0.4690	0.1020
C. D. 5%	0.5944	0.3715	1.1019	1.3404	0 2906
C. D. 1%	0.7953	0.4970	1.4743	—	—

@ Sarup *et al.*, 1974
\+ Log values after adding one to original mean (parentheses).
* Significant at 5% level
** Significant at 1% level
H. S. Highly significant.

TABLE 2 @

Average population of mustard aphid *Lipaphis erysimi* Kalt. at different intervals after the application of various formulations of insecticidal granules in soil before sowing.

Formulation		Per cent increase (−) or decrease (+) after 36 days	+ Average population after (days) 1st application before sowing 47	74	2nd application as side dressing 5	13	20	Average yield (gm/plot)
Formulated								
Lindane	D	− 33.33**	1.6803	3.1007	3.5252	3.4857	2.0702	17.02
	P	− 33.33**	1.2491	3.0708	3.5494	3.5099	1.9508	12.55
Dimetho_te	D	− 33.33**	1.7982	3.0013	3.4187	2.8090	2.1998	49.50
	P	+ 0.00**	1.5982	2.5[illegible]14**	2.4317*	2.4394*	1.9276	94.75*
Phorate	D	+ 33.33**	1.1815	2.5360**	2.1776**	2.6044	1.7038*	101.[illegible]5**
	P	+100.00**	0.7854**	2.3997**	1.7956**	1.9754**	1.5287*	100.75**
Disulfoton	D	+100.00**	0.7152**	2.4319**	1.4747**	1.7457**	0.9280**	136.75**
	P	+ 0.00**	0.5614**	2.0228**	1.5698**	1.8804**	0.6749**	123.00*
Phosphamidon	D	− 200.00	0.9569*	3.2146	3.2435	2.8267	2.6218	16.63
	P	− 66.67*	1.6309	3.3184	3.1994	2.6402	2.8189	11.75
Aphidan	D	− 100.00*	1.4308	2.9891	3.26[illegible]0	3.0884	2.3910	26.04
	P	− 133.33	1.4520	3.1522	3.3497	3.2076	2.5766	8.52
Control		− 233.33	1.7705	3.6991	3.6991	Plants dead	Plants dead	0.02

Table 2—(*contd.*)

Formulation	Per cent increase (−) or decrease (+) after 36 days	+ Average population after (@days)						Average yield (gm/plot)
		1st application before sowing		2nd application as side dressing				
		47	74	5	13	20		
Proprietary								
Dimethoate	−133.33	1.9114	3.0883	2.9940	2.6957	1.6281*		28.28
Disulfoton	+100.00**	0.1945**	1.5757**	0.0000**	1.3985**	0.0000**		189.25**
Lindane	−333.33	1.8978	3.1900	3.2631	3.1397	1.5149*		1.10
Phorate	+100.00**	1.0178*	2.7877*	1.8959**	2.5459*	1.7277*		125.50*
Carbofuran	−100.00**	1.7277	2.7252**	0.4269**	0.9280**	0 0000**		167.50**
Aphidan	−233.33	1.4450	3.1445	2 1759**	2.1045**	0.8538**		65.77*
Monocrotophos	−300.00	2 0366	3.2745	3.4931	2.9253	2.1673		3.81
Aldicarb	+100.00**	0.9266**	1.6218**	0.5011**	0.5447**	0.0000**		211.6*
'F' test	H. S.	H. S.	H. S.	H. S.	H. S	H. S.		H. S.
S. Em. ±	44.38	0.2193	0.2555	0.4041	0.3300	0.3839		20.86
C. D. 5 %	126.82	0.6202	0.7225	1.1428	0.9351	1.0878		58.99
C. D. 1 %	169.98	0.8248	0.9610	1.5199	1.2454	1.4480		78.46

@ Sarup *et al.*, 1971
* Significant at 5 % level
** Significant at 1 % leval
\+ Log values after adding one
H. S. Highly Significant

were more effective than corresponding deactivated and proprietary formulations. The formulated granules of lindane, phosphamidon and aphidan were practically ineffective (Sarup *et al.*, 1971).

Detailed investigations were further carried out on the aphicidal action of different formulations of BHC, lindane, phorate and disulfoton applied in soil before sowing. Their performance in relation to individual insecticide were as follows :

BHC : Among the granular formulations based on plain carriers without binder, and prepared by surface coating and impregnation, the most effective ones were Bento/Sc., Kao./Sc.. and Pyro./Sc. (Table 3), which were superior to control and proprietary granules in terms of low aphid population and high yield of mustard seed (Sircar, 1976). Surface coated granules were more effective than corresponding impregnated granules in the case of above formulations.

The formulation of lindane, phorate and disulfoton were based on plain carriers, different binders and prepared by surfrce coating and impregnation In the case of phorate and disulfoton, the carriers, attapulgite, fuller's earth, kaolimite and magnesite were also deactivated by means of HMT.

Lindane : Considering lowest aphid population and maximum yield, the most effective aphicidal formulations were Gyp./Sc. and Kao./Cel./Sc. (Table 3). These were superior to the proprietary granules also. The superior aphicidal efficacy of Kao/Cel./Sc. as against Kao./Cel./Imp. brought out the importance of the method of formulation, while the other components, viz., carrier and binder were identical. Improved aphicidal properties of Kao./Cel./Sc. as compared to Kao./GA/Sc. and Kao./S. sil./Sc. indicated the importance of suitable binder. The effect of a compatible carrier was evident from the superior efficacy of Kao./Cel./Sc. as compared to that of Ch. clay/Cel./Sc. (Sircar, 1976).

It may thus be inferred that the binder methyl cellulose and gelatina improved the efficacy of the formulation against the mustard aphid, as against gum *Acacia* and sodium silicate. Among the most effective formulations the granules prepared by surface coating were superior to impregnated granules. The binders had an adverse effect on the aphicidal efficacy of Atta/GA./Sc., Bento./GA./Imp., F.E./GA./Imp., which resulted in as high an aphid population as in control as compared to their corresponding formulation without binder.

TABLE 3 @

The most effective formulations of different insecticidal granules against *L. erysimi* and *A. gossypii.*

Insecticide	Aphid pests	
	L. erysimi	*A. gossypii*
BHC	Bento. / Sc., Kao. / Sc., Pyro. / Sc.	Atta. / Imp., F. E. / Imp. F. E. / Sc., Ch. clay / Sc., Gyp. / Sc.
Lindane	F. E. / Sc., Kao. / Sc., Ch. clay./Sc., Mag./Sc., *Gyp./Sc.,* Bento./Cel./Sc., F. E. / Ge. / Sc., Kao. / Ge. / Sc., *Kao., / Cel. / Sc.,* Mag. / S. sil. / Imp., Dolo. / Cel. / Sc., Qtz. / Cel. / Sc.	Atta. / Sc., Bento. / Imp., F. E. / Imp., F. E. / Sc.
Phorate	*Gyo./Sc., Pyro./Sc., Atta./G.A./Sc.,* Atta. / Cel. / Sc., Bento. / G.A. / Sc., *F.E. / Cel. / Sc., Mag. / Cel. / Imp., Mag. / Cel. / Sc., Talc. / Cel. / Imp., Qtz. / Cel. / Imp.*	Kao. / Sc., Diato. / Imp. Pyro. / Imp. Pyro. / Sc.
Disulfoton	Atta. / Sc., Gyp. / Sc., *Kao. / Sc., Ch. clay / Sc.,* Atta. / Ge. / Imp. Bento. / Ge. / Imp., Bento. / Cel. / Imp., *Kao. / Ge. / Imp., Ch. clay / G. A. / Sc.,* Ch. clay. / Ge. / Imp. Mag. / cel. / Imp., *Diato. / Ge. / Sc.,* Dolo. / Ge. / Imp., Talc. / S. sil. / Imp., *Talc / Ge. / Imp.,* Qtz. / Ge. / Imp., Qtz. / cel. / Imp.	F. E. / Sc. Dolo. / Sc. Qtz. / Sc.

@ Sircar, 1976.

Phorate: The most effective formulations were Gyp./Sc., Pyro./Sc., Atta/GA./Sc., F.E./Cel./Sc., Mag./Cel./Imp. & Sc., Talc/Cel./Imp. and Qtz./Cel./Imp., which were even superior to proprietary formulations (Table 3). The method of formulation resulted in superior aphicidal efficacy of Atta./GA./Sc as compared to Atta./GA./Imp., whereas no such difference could be observed in the case of Mag./Cel./Imp. and Mag./Cel./Sc. Addition of binder methyl cellulose improved the residual action of Mag./Cel./Imp. over that of Mag./Imp. The nature of binder viz., methyl cellulose, resulted in superior efficacy of Mag./Cel./Sc., as against that of Mag./S. sil./Sc., formulated with the binder sodium silicate. The residual aphicidal action in the case of Mag./Cel./Sc. than in the case of Kao./Cel./Sc. was obviously due to a difference in the nature of the granular carrier.

In the case of formulations without binders, plots treated with surface coated granules exhibited lesser number of aphids than those treated with impregnated formulations. This trend was, however, reversed when sodium silicate binder was used in the granules, formulated with attapulgite, bentonite, diatomite, and pyrophyllite as carriers. In the case of surface coated chinaclay granular formulations, sodium silicate imparted a slow and regulated release, the performance being better than that of the impregnated granules. The surface coated granules of fuller's earth regardless of the binders used were more effective against mustard aphid than the corresponding impregnated granules. The impregnated granules of kaolimite were superior to the surface coated formulations, irrespective of the nature of binder used. Deactivation of attapulgite, fuller's earth, kaolinite and magnesite with HMT did not improve the aphicidal efficacy (Sircar, 1976).

Disulfoton: The most effective formulations with least aphid population and highest yield as compared to control and the proprietary granules were, Kao./Sc., Ch. clay/Sc., Kao./Ge./Imp., Ch. clay/GA./Sc., Diato./Ge./Sc. and talc/Ge./Imp. (Table 3). The effect of the method of formulation was evident with the superior efficacy or Ch. clay/GA./Sc, over that of Ch. clay/GA./Imp. The formulation Ch. clay/GA./Sc. was a better aphicide than Ch. clay/S. sil./Sc., due to the difference in the nature of the binder. The carrier effect was obvious in the case of Ch. clay/GA./Sc. as against Kao./GA./Sc. The addition of binder improved the persistence of Kao./Ge./Imp. as compared to Kao./Imp., whereas an adverse effect was imparted by gum *Acacia* in the case of Kao./GA./Sc. as compared to the superior efficacy of Kao./Sc.

The surface coated granules without binders were better than impregnated granules, except in the case of fuller's earth and pyrophyllite. Aphicidal efficacy of the granules was differently modified by incorporating different binders, depending on the method of formulation. Thus gum *Acacia* improved the efficacy of attapulgite, bentonite, diatomite and quartz by impregnation, and pyrophyllite by surface coating. The binder gelatine imparted longer residual action with attapulgite, bentonite, fuller's earth, chinaclay, diatomite, talc and quartz by impregnation; and bentonite, diatomite and pyrophyllite by surface coating Methyl cellulose improved the aphicidal efficacy of attapulgite, bentonite, fuller's earth, chinaclay, diatomite, magnesite, gypsum, dolomite, talc and quartz by impregnation; and that of attapulgite, fuller's earth, magnesite, pyrophyllite and quartz by surface coating. The same trend was observed when sodium silicate was incorporated in impregnated attapulgite, bentonite, chinaclay, gypsum, talc, and quartz. The deactivator HMT adversely affected the aphicidal action of formulations based on kaolinite and magnesite (Sircar, 1976). The residues of disulfoton in the soil and seeds of mustard ranged from 0.00 to 0.26 ppm and 0.00 to 1.48 ppm (Tolerance 0.05 ppm), respectively depending upon the nature of formulation (Sircar, 1976).

Thus, considering the overall data, it was observed that against mustard aphid, surface coated formulations without binder were relatively more effective than impregnated granules. The effect of binders was pronounced depending upon the carrier and method of formulation. Deactivation did not improve the aphicidal efficacy of phorate and disulfoton.

(iii) *Evaluation of aphicidal efficacy against* Lipaphis erysimi *Kalt., infesting cabbage*

Different formulations of 4 % and 2 % endosulfan granules based on six diluents and prepared by surface coating and impregnation were evaluated as foliar (whorl) treatment. Minimum aphid population was recorded in the case of 4 % talc (Sc.), 4 % magnesite (Sc.), 2 % fuller's earth (Imp.), 4 % chinaclay (Imp.) and 2 % diatomite (Imp.), 30 days after treatment. These were significantly better than control, proprietary granules and emulsion concentrates. Considering overall aphid population, 4 % endosulfan granules based on chinaclay and prepared by impregnation was found to be most effective (Sircar *et al.*, 1979). In the case of some of the formulations, higher concentration (4 %) formulations were found to be less effective than corresponding lower concentration (2 %) formulations. This was evident in the case of surface coated fuller's earth, and impregnated fuller's earth and diatomite, 30 days after granular treatment (Table 4). At present, this can only be explained on the basis of certain physical limitations imparted to higher concentration formulations, resulting in non-availability of effective dose of the insecticide, and/or physical avoidance by the aphids. Nevertheless, the above finding indicated that some of the formulations of endosulfan granules afforded maximum protection against aphid population involving minimum effective dose. A lower concentration effective formulation will also involve judicious use of insecticide resulting in minimum health hazard.

The residues of endosulfan from different formulations 14 and 30 days after treatment were non-detectable in most of the cases. However, low residues below the tolerance limit of 2.0 ppm were detected from 2 % chinaclay (Imp. & Sc.), 4 % fuller's earth (Sc.), 4 % bentonite (Sc.), 4 % & 2 % diatomite (Sc.) and proprietary granules, 14 days after treatment. This declined to non-detectable level after 30 days in all the treatments except 4 % fuller's earth (Sc.), 2 % diatomite (Sc.), and proprietary granules which however gave residues below tolerance limit. The nature of formulation, thus not only determined aphicidal efficacy but also the ultimate residue of the insecticide (Sircar, 1976).

(iv) Evaluation of aphicidal efficacy against
Aphis gossypii *Glover infesting okra crop*

The granular formulations of BHC, lindane, phorate and disulfoton based on plain carriers without binder and prepared by impregnation and surface coating were evaluated as soil treatment before sowing.

BHC : The most effective formulation against cotton aphids (Table 3) were Atta./Imp., F. E./Imp., F. E./Sc., Ch. clay/Sc. and Gyp./Sc. These were also superior to control and proprietary granule (Sircar, 1976). The surface coated formulation of attapulgite and pyrophyllite were more effective than their corresponding impregnated granules, thus indicating the effect of method of formulation. Both the formulations of F. E./Imp. and F. E./Sc. were most effective, since the carrier effect was more pronounced than that of the method of formulation. Incidentally, the granular formulation Atta./Imp. was not only most effective against the aphids but also against the pest complex of okra crop.

TABLE 4 @

Average population of *Lipaphis erysimi* infesting cabbage at different intervals after foliar application of various formulation of endosulfan granules.

Formulation	Average aphid population * after days			Residue (ppm) after (days)
	7	14	30	30
Talc / 4% / Imp.	4 82	7.63	10.27	ND
Talc / 2% / Imp.	5.01	7.00	9.05	,,
Talc / 4% / Sc.	6.51	9.35	3.06	,,
Talc / 2% / Sc.	7.93	4.66	12.34	,,
Ch. clay / 4% / Imp.	0.71	2.72	4.78	,,
Ch. clay / 2% / Imp.	10.46	8.53	8.49	,,
Ch. clay / 4% / Sc.	6.14	6.05	9.53	,,
Ch. clay / 2% / Sc.	5.55	4.46	14.81	,,
Mag. / 4% / Imp.	1.87	6.80	6.63	,,
Mag. / 2% / Imp.	1.79	0.71	5.18	,,
Mag. / 4% / Sc.	5.83	5.72	3.88	,,
Mag. / 2% / Sc.	5.88	8.24	6.30	,,
F. E. / 4% / Imp.	3.51	9.75	7.16	,,
F. E. / 2% / Imp.	3.57	4.51	4.32	,,
F. E. / 4% / Sc.	11.61	11.80	11.68	0.01
F. E. / 2% / Sc.	3.69	2.43	9.78	ND
Bento. / 4% / Imp.	9.23	5.33	7.89	,,
Bento. / 2% / Imp.	9.24	12.61	11.15	,,
Bento. / 4% / Sc.	8.49	9.57	8.42	,,
Bento. / 2% / Sc.	4.08	6.30	16.86	,,
Diato. / 4% / Imp.	7.17	0.71	8.69	,,
Diato. / 2% / Imp.	6.05	5.72	4.99	,,
Diato. / 4% / Sc.	5.46	6.15	7.22	,,
Diato. / 2% / Sc.	1.68	7.00	12.12	0.01
Proprietary granules	1.96	4.57	6.80	0.01
Proprietary emulsion	4.08	5.46	9.35	ND
Control	19.68	16.30	Plants dead	Plants dead
'F' test	Sign.	Sign.	Sign.	
S Em ±	0.279	0.409	0.640	
C D. 5 %	0.786	1.150	1.790	
C. D. 1 %	1.042	1.525	2.370	

@ Sircar *et al.*, 1979 ND Not detectable.

* Transformed valves $\sqrt{x + 0.5}$

Lindane: The most effective formulations, significantly better than control and the proprietary granules were Atta./Imp., Atta./Sc., Bento./Imp. and F. E./Sc. (Table 3). Thus, no effect of method of formulation on the aphicidal efficacy of attapulgite granules was apparent whereas, impregnation and surface coating were the suitable methods for bentonite and fuller's earth granules, respectively. The formulations Atta./Imp. and F. E./Sc were thus most compatible aphicidal combinations for both the chlorinated hydrocarbon insecticides, BHC and lindane (Sircar, 1976).

Phorate: The granular formulations significantly more effective against cotton aphid than control and proprietary granules were (Table 3) Kao./Sc., Diato./Imp. & Sc., and Pyro./Imp. & Sc. Thus, only surface coating of the insecticide in the case of kaolimite, and either surface coating or impregnation in the case of diatomite and pyrophyllite were the most suitable methods for maximum residual action against the aphid population infesting okra crop (Sircar, 1976).

Disulfoton: The consistently most effective formulations of F. E./Sc., Dolo./Sc. and Qtz./Sc. were superior to the proprietary granules only initially upto 40 days after treatment (Table 3). However, F. E./Sc. was the most persistent formulation against the pest complex of okra crop (Sircar, 1976).

It is thus evident that the residual action of granules of organic insecticides against various aphid pests infesting mustard, pea, okra and cabbage crops was modified by the inorganic mineral carrier, the binder, deactivator and the method of formulation. The results highlight a judicious use of insecticides incorporating suitable carriers and other prerequisites in a granular formulation for maximum aphicidal efficacy, superior yield and minimum insecticidal residues.

ACKNOWLEDGMENT

The authors are thankful to the Head of the Division of Entomology, IARI, New Delhi-12, for providing necessary facilities and encouragement.

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EVALUATION OF INSECTICIDES FOR APHICIDAL ACTIVITY

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ABSTRACT

Rapid introduction of newer insecticides necessitates a rapid evaluation of their aphicidal activity in relation to different species, relative susceptibility and resistance values, safety margin for predators, different hosts, ecological conditions and any change in susceptibility level or development of resistance. The available information may thus serve as a ready reckoner for inclusion or otherwise in extensive trials of a control schedule programme. Although the specificity of various insecticides to different aphid species varied in order of efficacy, yet carbamates, organophosphates and lindane were found to be better aphicides as compared to pp. DDT and cyclodienes (except endosulfan). Insecticides of plant origin also proved superior against some of the aphid species, whereas, alcoholic extract of neem seed cake exhibited some degree of aphicidal activity. The relative resistance level of various aphid species differed widely with different insecticides, and a variation in susceptibility level of mustard aphid infesting different hosts was observed. Terrestrial species of aphids were found more resistant than aquatic species to most of the insecticides. A decrease in the toxicity of some of the insecticides against mustard aphid over a period of two years called for a periodical checking of susceptibility level for the detection of possible development of resistance. Comparative toxicity studies against various aphid species in relation to different parameters brought out the versatility of endosulfan, lindane and aphidan as effective aphicides.

INTRODUCTION

Periodical introduction of newer insecticides has necessitated a rapid evaluation of their aphicidal activity and related parameters. The available information may thus serve as a ready reckoner for inclusion or otherwise in extensive trials of a control schedule programme. It is thus essential that, for a correct appraisal of the aphicidal activity of the available insecticides, a number of criteria have to be highlighted. These include evaluation of relative toxicity against individual aphid species, specificity of insecticides, relative susceptibility or resistance of different species, differential susceptibility due to host or environment and a comparative data on the safety margin for important aphid predators. The investigations carried out by various workers (Jotwani *et al.*, 1960; Sarup *et al.*, 1959, 1961, 1964, 1966, 1967, 1969 a & b, 1971; Abhayankar and Sarup, 1970; Singh *et al.*, 1978, 1979) against important aphid pests of agricultural crops and their predator *Coccinella septempunctata* Linn., provide the relevant data for a comparative evaluation.

MATERIALS AND METHODS

The insecticides used in the various investigations were formulated from pure or technical grade materials using benzene as a solvent (acetone for carbaryl) and triton x 100 as emulsifier. The solvent and emulsifier levels in the final spray were maintained at 5.0 and 0.625 per cent, respectively. The various aphid species were field collected from respective hosts and preconditioned in the laboratory at 27 ± 1°C. A specific number of apterous, viviparous adult females were subjected to 1 ml of the spray material under Potter's tower at 24 cm mercury pressure. The treated insects after drying, were transferred to tubes containing uninfested host plant material as food and kept at 17 ± 1°C. Mortality counts were taken 24 hours after the treatments. Each experiment was replicated thrice and five to six concentrations of each insecticide were tested to obtain the concentration probit mortality curve. The data were subjected to probit analysis (Finney, 1952) after suitable transformations.

RESULTS AND DISCUSSION

The criteria for evaluation of aphicidal activity of insecticide based on LC_{50} values are discussed in relation to different parameters.

(a) *Relative toxicity of insecticides against different aphid species*

Aphis craccivora Koch.

The most toxic insecticide was found to be phorate with an LC_{50} value of 0.0000073 (Table 1). The organophosphates were relatively more toxic as compared to other groups of insecticides (Sarup *et al.*, 1969).

Aphis gossypii Glover.

Although relatively less toxic as against ***A. craccivora*** phorate (0.00036) was found to be most toxic (Table 1), followed by carbaryl (0.00055). The particular aphid species was found to be relatively more resistant to the insecticides tested as compared to ***A. craccivora*** (Jotwani ***et al.***, 1960).

Brevicoryne brassicae Linn.

Among the various insecticides tested, dimethoate with an LC_{50} value of 0.000096 proved most toxic (Table 1). Organophosphates and rotenone were relatively superior to organochlorine and carbamate insecticides. Carbaryl (0.0686) was virtually ineffective for field application (Sarup ***et al.***, 1966).

Dactynotus carthami H. RL

Phorate (0.000194) followed by phosphamidon, rotenone and endosulfan were the most toxic aphicides (Table 1). The aphid species was more resistant to insecticides as compared to ***A. craccivora*** (Sarup ***et al.***, 1964).

Lipaphis erysimi Kalt.

The most effective insecticides were phosphamidon (0.000032) and dimethoate (0.000047) (Table 1) whereas, carbaryl and endosulfan were less effective aphicides as compared to lindane (Sarup ***et al***,, 1969).

Myzus persicae Sulz.

The most toxic aphicides with low LC_{50} values were dimethoate (0.00015) and phosphamidon (0.00019) although less toxic as against ***L. erysimi*** (Table 1). Organophosphates were relatively more potent aphicides as compared to other groups (Sarup ***et al.***, 1967).

Rhopalosiphum maidis (Fitch)

Carbaryl (0.00012) followed by malathion (0.00013) were relatively most toxic insecticides (Sarup ***et al.***, 1961), while lindane was less toxic with an LC_{50} value of 0.0038 (Table 1).

(*b*) *Specificity of insecticides*

It is evident from Tables 1 and 2 that the specificity of the insecticides varied according to the aphid species. Thus, phorate against *A. craccivora*, *A. gossypii* and *D. carthami*; dimethoate against *B. brassicae* *L. erysimi* and *M. persicae*; carbaryl against *A. gossypii* and *R. maidis*; and phosphamidon against *D. carthami*, *L. erysimi* and *M. persicae* were relatively the most toxic aphicides. On the other hand, carbaryl proved to be least toxic against *B. brassicae* and *L. erysimi*, the two important pests of cruciferous crops. An interesting relationship regarding aphicidal activity of ten common insecticides evaluated against all the seven aphid species (Table 2) is thus revealed. It may be noted that there was a remarkable shift in the order of toxicity of the ten insecticides in relation to different aphid species. Insecticides of carbamate group (carbaryl), organophosphates (malathion and parathion) occupied upper half in the order of toxicity, with the exception of carbaryl occupying fifth and sixth positions against *L. erysimi* and *B. brassicae* respectively. The non-cyclodiene chlorinated hydrocarbon, lindane also occupied the upper half in order of toxicity, except in case of *A. craccivora* and *B. brassicae* (Sarup *et al.*, 1969). It may thus be reasonably generalised that considering the degree of toxicity, carbamate (carbaryl), organophosphate (malathion and parathion) and lindane were better aphicides as compared to p,p' DDT and the cyclodiene insecticides.

(*c*) *Relative susceptibility/resistance of aphids to different pesticides*

A comparison of the LC_{50} values of different insecticides for various aphid species in relation to *L. erysimi* provided the relative susceptibility or reistance level of the aphid species. It is evident (Table 1) that *L. erysimi* was more susceptible than *M. persicae* to all the pesticides except carbophenothion and chlorobenzilate. *B. brassicae* was more resistant to the pesticides than *L. erysimi* except rotenone, carbophenothion and formothion. With the exception of carbophenothion and endosulfan, *D. carthami* was more resistant than *L. erysimi*. However, *L. erysimi* was more resistant than *R. maidis* to chlordane, carbaryl, malathion and parathion, whereas, *A. gossypii* was more resistant than *L. erysimi* to all the pesticides except carbaryl and aldrin (Sarup *et al.*, 1969). The susceptibility level of *A. craccivora* and *L erysimi* to dimethoate and phosphamidon were almost identical.

TABLE

Relative resistance of different

Pesticide	LC$_{50}$ values for					
	Myzus persicae[1]	*Brevicoryne brassicae*[2]	*Dactynotus carthami*[3]	*Rhopalosiphum maidis*[4]	*Aphis gossypii*[5]	*Lipaphis erysimi*[2]
Dimethoate	0.0001544	0.00000581	—	—	—	0.00004708
Phosphamidon	0.0001954	0.0001347	0.0004015	—	—	0.00003198
Methyl parathion	0.0002733	0.0001197	—	—	—	0.00005552
Parathion	0.0003795	0.001162	0.001442	0.0001306	0.001198	0.00019720
Morphothion	0.0005653	0.0001802	—	—	—	0.00006621
Rotenone	0.0006870	0.0001694	0.0006936	—	—	0.00030340
Aphidan						0.00044920
Phorate	0.0008650	0.001106	0.0001936	—	0.0003517	0.00008802
Carbophenothion	0.001116	0.0002642	0.0009956	—	—	0.0040020
Malathion	0.002375	0.001166	0.001528	0.0001280	0.001705	0.00106800
Lindane	0.003538	0.1123	0.008523	0.003814	0.004236	0.00100700
Formothion	0.003649	0.0009638	—	—	—	0.0018280
EPN	0.004401	0.007400	—	—	—	0.00051290
Diazinon	0.009272	0.003322	0.002004	—	0.007568	0.00103200
Pyrethrins	0.009759	0.001809	0.004467	—	—	0.00126600

Endosulfan	0.01062	0.007231	0.0006988	—	0.010700	0.0030420
Carbaryl	0.01544	0.06860	0.003046	0.0001160	0.0005512	0.0016270
Endrin	0.01939	0.01153	0.01154	0.004355	0.008441	0.00077290
Dichlorvos	0.02518	0.02786	0.02132	—	—	0.00105900
Isodrin	0.04152	0.06600	0.07050	0.017910	0.007006	0.0065700
Nicotine sulphate	0.07649	0.4079	0.14570	—	—	0.0138000
Dieldrin	0.1757	0.02413	0.07590	—	0.056010	0.0221200
Heptachlor	0.1850	0.2828	0.81060	—	0.241600	0.0092940
Orthodibrom	—	—	—	—	—	0.0035620
p,p' DDT	0.2615	0.2294	0.12990	0.018170	0.026810	0.0040940
Chlordane	0.3151	0.1883	0.55260	0.013430	0.225800	0.0145300
Toxaphene	0.3595	0.1754	0.09024	0.041260	0.053360	0.0358300
Bromodan	0.4181	0.1967	—	—	—	0.0132700
Aldrin	0.4221	0.05331	0.69370	0.029670	0.015580	0.0188800
Chlorobenzilate	0.5646	>1.0%	—	—	—	>1.0%
Trichlorphon	>1.0%	0.7245	—	—	0.088160	0.0051980
Thanite	>1.0%	0.54120	0.50390	—	—	0.0498400
	[1]Sarup *et al*, (1967)	[2]Sarup *et al*, (1966)	[3]Sarup *et al*, (1964)	[4]Sarup *et al* (1961)	[5]Jotwani *et al*, (1960)	[6]Sarup *et al* (1969)

—denotes that the pesticides were not tested.

1

species of aphids to pesticides.

Aphis craccivora[7] (infesting cowpea)	Aphis craccivora (infesting pea)	Relative resistance*						
		Myzus persicae	Brevicoryne brassicae	Dactynotus carthami	R. maidis	Aphis gossypii	Aphis craccivora (on cowpea)	Aphis craccivora (on pea)
—	0.00003955	3.28	2.03	—	—	—	—	0.84
—	0.00002823	6.11	4.21	12.55	—	—	—	0.88
—	0.00008849	4.92	2.15	—	—	—	—	1.59
0.0007293	0.00007150	1.92	5.89	7.31	0.66	6.07	3.70	0.26
—	0.0001452	8.54	2.72	—	—	—	—	2.19
—	—	2.26	0.56	2.29	—	—	—	—
—	0.001839	—	—	—	—	—	—	4.09
—	0.000007319	9.83	12.56	2.20	—	4.11	—	0.08
—	0.001764	0.28	0.066	0.25	—	—	—	0.44
0.0008670	0.0003438	2.22	1.09	1.43	0.12	1.60	0.81	0.32
0.002603	0.001861	3.51	111.51	8.46	3.79	4.21	2.58	1.85
—	0.0006240	2.00	0.53	—	—	—	—	0.34
—	0.00009712	8.58	14.43	—	—	—	—	0.19
—	0.0005505	8.98	3.22	1.94	—	7.33	—	0.53
—	0.0003017	7.71	1.43	3.53	—	—	—	0.24

—	0.003859	3.49	2.38	0.23	—	3.52	—	1.27
0.0005546	0.0006759	9.49	42.16	1.87	0.07	0.34	0.34	0.41
0.0003064	0.001383	25.09	14.92	14.91	5.63	10.92	0.40	1.79
—	0.0001921	23.78	26.31	20.13	—	—	—	0.18
0.002971	0.001515	6.32	10.04	10.73	2.73	1.07	0.45	0.23
—	0.006797	5.54	29.56	10.56	—	—	—	0.49
0.002029	0.01044	7.94	1.09	3.48	—	2.53	0.09	0.47
0.017790	—	19.90	30.43	87.21	—	25.99	1.91	—
—	0.0001446	—	—	—	—	—	—	0.04
0.021000	0.02511	63.87	56.03	31.73	4.44	6.55	5.13	6.13
0.0244600	0.0128300	21.69	12.96	38.03	0.92	15.54	1.68	0.88
0.019980	0.0462400	10.03	4.89	2.52	1.15	1.50	0.56	1.29
—	—	31.51	14.82	—	—	—	—	—
0.028220	0.04956	22.35	2.82	36.74	1.57	0.88	1.49	2.62
—	—	Low	≈	—	—	—	—	—
—	0.01522	Very high	139.38	—	—	16.96	—	2.93
—	—	High	10.86	10.11	—	—	—	—

[7]Sarup *et al.* (1960)

$$\text{*Relative resistance} = \frac{LC_{50}\text{ value of an insecticide for a particular aphid species}}{LC_{55}\text{ value of the same insecticide for } L.\ erysimi}$$

TABLE 2

The order of toxicity of ten pesticides tested against all the seven aphid species.

Aphid species / Pesticide	R. maidis[1]	A. gossypii[2]	D. crathami[3]	B. brassicae[4]	M. persicae[5]	L. erysimi[6]	A. craccivora[7] (infesting cowpea)	A. craccivora (infesting pea)
Carbaryl	1	1	3	6	4	5	2	3
Malathion	2	3	2	2	2	4	4	2
Parathion	3	2	1	1	1	1	3	1
Lindane	4	4	4	7	3	3	5	6
Endrin	5	6	5	3	5	2	1	4
Chlordane	6	10	9	9	8	8	9	7
Isodrin	7	5	6	5	6	7	6	5
p,p' DDT	8	8	8	10	7	6	8	8
Aldrin	9	7	10	4	10	9	10	10
Toxaphene	10	9	7	8	9	10	7	9

[1]Sarup *et al.* (1961) [2]Jotwani *et al.* (1960) [3]Sarup *et al.* (1964) [4]Sarup *et al.* (1966) [5]Sarup *et al.* (1967) [6]Sarup *et al.* (1969) [7]Sarup *et al.* (1960)

(*d*) *Differential susceptibility due to hosts*

A wide variation in the aphicidel activity of insecticides against a particular aphid species infesting different hosts could be observed. The mustard aphid ***L. erysimi*** infesting cabbage was most susceptible to insecticides belonging to different groups except p,p' DDT and carbaryl (Abhayankar and Sarup, 1970). Whereas the same species when reared on knolkol was least susceptible except to malathion (Table 3). The aphids reared on turnip, mustard, radish and cauliflower occupied intermediate position on the order of susceptibility to all the insecticides except to p,p' DDT, lindane, carbaryl and malathion. It is suggested that for the control of the aphid infesting different hosts, varied concentrations of insecticides to which they are susceptible may prove to be economical.

TABLE 3

Relative toxicity of various insecticides to *L. erysimi* reared on different host plants.

Insecticides	Mustard		Cabbage		Cauliflower		Knolkhol		Turnip		Radish	
	R.T.	O.T.	R.T.	O.T.	R.T.	O.T.	R.T.	O.T.	R.T.	O.T.	R.T.	O.T.
Phosphamidon	416.235	1	403.940	2	710.175	1	490.317	1	1043.313	1	882.333	1
Dimethoate	253.511	2	420.512	1	437.500	2	286.732	2	742.362	2	582.777	2
Ethyl parathion	77.519	4	261.682	3	202.025	3	130.304	4	360.604	3	219.902	3
Methyl parathion	119.786	3	245.666	4	98.721	4	154.909	3	236.520	4	200.370	4
Malathion	20.704	5	44.984	5	65.841	5	28.541	5	12.977	7	9.630	7
Endrin	10.681	6	24.224	6	27.041	6	20.780	6	50.936	5	46.194	5
Endosulfan	4.145	7	7.139	7	10.156	7	7.168	7	16.067	6	11.741	6
Lindane	3.545	8	1.573	9	3.474	8	3.029	8	3.163	10	3.236	8
Nicotine sulphate	0.901	11	3.028	8	1.833	9	1.106	9	3.687	8	2.220	9
p,p' DDT	1.000	10	1.000	10	1.000	11	1.000	10	1.000	11	1.000	11
Carbaryl	2.329	9	0.687	11	1.388	10	0.934	11	3.401	9	1.840	10
Nicotine	0.169	12	0.398	12	0.359	12	0.121	12	0.825	12	0.200	12

R.T. — Relative toxicity. ; O.T. — Order of toxicity.

$$\text{Relative toxicity} = \frac{LC_{50} \text{ of p,p' DDT for } L.\ erysimi \text{ reared on a particular host}}{LC_{50} \text{ of other insecticides for } L.\ erysimi \text{ reared on the same host}}$$

TABLE

Relative resistance of *Coccinella* ... comparison to *Aphis craccivora*

Pesticide	LC_{50} of *A.craccivora* on *Bean* @	LC_{50} of *A.craccivora* on *Pea* *	LC_{50} of *A.craccivora* on *Cowpea* **	LC_{50} of *Coccinella septempunctata* gurb *** (i & iii)	adult *** (ii)
Phosphamidon	0.00001	0.00002823	—	0.000230	0.002649
Dimethoate	0.00004683	0.00003955	—	—	—
Dichlorovos	0.00006874	0.0001921	—	0.015850	0.003321
Phenthoate	0.00015555	0.006074	—	0.001663	—
Fenitrothion	0.0001585	0.0004048	—	0.006412	—
Ehtyl parathion	0.0001811	0.00007150	0.0007293	0.002818	0.004454
Leptophos	0.0002219	—	—	0.076370	—
Methyl parathion	0.0002444	0.00008849	—	0.001945	—
Malathion	0.0002666	0.0003438	0.0008670	0.001020	—
Formothion	0.0003552	0.0006240	—	0.001380	—
Orthodibrom	0.0004900	0.0001446	—	0.015130	—
Carbaryl	0.0005690	0.0006759	0.0005546	—	—
Pyrethrums	0.0006604	0.0003017	—	—	0.046920
Phorate	0.0006194	0.00003719	—	0.000015	0.000984
Trichlorphon	0.0008061	0.01522	—	0.297800	0.015140
Morphothion	0.001117	0.0001452	—	—	—
Aphidan	0.001124	0.001839	—	>1.0	—
Diazinon	0.001538	0.0005505	—	0.000977	1.169000
Lindane	0.002021	0.001861	0.002603	0.337500	—
Endosulfan	0.002252	0.003859	—	>1.0	0.274200
Rotenone	0.003467	—	—	0.070530	0.524100
E. P. N.	0.003715	0.00009712	—	—	—
p,p' DDT	0.01896	0.02511	0.024460	0.452100	—

4

septempunctata group and adult in infesting different hosts.

Bean		*Pea*		*Cowpea*	
Coccinella grub	*Coccinella* adult	*Coccinella* grub	*Coccinella* adult	*Coccinella* grub	*Coccinella* adult
23.00	246.90	8.15	93.84	—	—
—	—	—	—	—	—
230.58	48.31	82.51	17.29	—	—
10.69	—	0.27	—	—	—
40.45	—	15.84	—	—	—
15.56	24.59	39.41	62.29	3.86	6.11
344.16	—	—	—	—	—
7.96	—	21.98	—	—	—
3.83	45.16	2.97	35.02	1.18	13.89
3.89	—	2.21	—	—	—
30.88	—	104.63	—	—	—
—	6.46	—	5.43	—	6.62
—	71.05	—	155.52	—	—
0.02	1.59	2.05	134.44	—	—
369.43	19.65	19.57	1.04	—	—
—	—	—	—	—	—
Very high	—	Very high	—	—	—
0.64	760.08	1.77	2123.52	—	—
167.00	—	181.35	—	—	—
Very high	121.76	Very high	71.05	—	—
20.34	151.17	—	—	—	—
—	—	—	—	—	—
23.84	—	18.00	—	18.48	—

* = Sarup *et al.*, 1969

** = Sarup *et al.*, 1960

* Relative resistance = $\frac{\text{LC 50 value for predator}}{\text{LC 50 value for the host}}$

*** = (i) Pradhan *et al.*, 1959

(ii) Sarup *et al.*, 1965

(iii) Singh *et al.*, 1978.

@ Singh *et al.*, 1979

— Denotes that the insecticide was not tested.

A comparative study against bean aphid, ***A. craccivora*** infesting bean, pea and cowpea (Singh ***et al.***, 1979) revealed that the aphids infesting bean were more susceptible to phosphamidon only as compared to those infesting pea crop (Table 4). The aphids infesting bean and pea crop were relatively more susceptible to ethyl parathion and malathion in relation to those infesting cowpea. It was evident that the insecticides tested against ***A. craccivora*** exhibited almost a similar order of toxicity in case of bean and pea crops. Actual LC_{50} values for individual aphid species infesting different hosts were almost identical in the case of carbaryl, lindane, and p-p' DDT (bean, pea and cowpea); dimethoate, malathion, aphidan and endosulfan (bean and pea). Keeping in view the toxicity to the aphid species and safety margin for the predator, ***C. septempunctata***, any one out of aphidan, lindane and endosulfan may be selected for aphid control.

(*e*) *Relative resistance of aphid species infesting terrstrial and aquatic plants*

The most toxic aphicides against *Rhopalosiphum nymphaeae* (Linn.) infesting aquatic ***singhara*** (***Trapa bispinosa***) plants, were pyrethrins and carbaryl (Sarup ***et al.***, 1971). It was evident that the seven aphid species referred to as infesting terrestrial plants were more resistant than those infesting aquatic ***singhara*** plants to most of the pesticides tested (Table 5).

(*f*) *Aphicidal activity of botanical product*

Against some of the important aphid pests of economic importance, the botanical insecticides have been found to be quite promising. Thus against tobacco aphid ***Myzus persicae***, rotenone was found to be 5 times more toxic than lindane (Sarup ***et al.***, 1967) and was appreciably superior to many organosphosphates, chlorinated hydrocarbon and carbaryl (Table 1). Rotenone and pyrethrins were found to be 662.9 and 62.1 times, respectively, more toxic than lindane against the cabbage aphid, ***B. brassicae*** (Sarup ***et al.***, 1966), and were also relatively superior to a number of organophosphates, chlorinated hydrocarbon and carbaryl. The superior aphicidal activity of rotenone and pyrethrins against ***D. carthami*** (Sarup ***et al.***, 1964) and ***L. erysimi*** (Sarup ***et al.***, 1969) in comparison to a number of modern synthetic insecticides was also observed. Rotenene exhibited a high safety margin of 1 : 766 for ***C. septempunctata***

TABLE

Relative resistance of different species of aphids infesting

Pesticide	LC$_{50}$ values for various aphid species infesting						
	aquatic	terrestrial plants					
	Singhara *Trapa bispinosa*	tobacco	cabbage	safflower	barley	brinjal	mustard
	Rhopalasiphum nymphaeae	[1]*Myzus persicae*	[2]*Brevicoryne brassicae*	[3]*Dactynotus carchami*	[4]*Rhopalosiphum maidis*	[5]*Aphis gossypii*	[6]*Lipaphis erysimi*
Pyrethrins	0.000006221	0.009759	0.001809	0.004467	—	—	0.00126600
Rotenone	0.00001578	0.0006870	0.0001694	0.0006936	—	—	0.00030340
Nicotine sulphate	0.02414	0.07649	0.4079	0.14570	—	—	0.013800
Thanite	0.2930	>1.0%	0.54120	0.50390	—	—	0.0498400
Carbaryl	0.000008468	0.01544	0.06860	0.003046	0.0001160	0.0005512	0.0016270
p,p' DDT	0.009881	0.2615	0.2294	0.12990	0.018170	0.026810	0.0040940
Lindane	0.0007794	0.003538	0.1123	0.008523	0.003814	0.004236	0.00100700
Aldrin	0.0003381	0.4221	0.05331	0.69370	0.029670	0.016580	0.0188800
Dieldrin	0.0002044	0.1757	0.02413	0.07590	—	0.056010	0.0221200

Heptachlor	0.04361	0.1850	0.2828	0.81060	—	0.241600	0.0092940
Endosulfan	0.0001004	0.01062	0.007231	0.0006988	—	0.010700	0.0030420
Parathion	0.0001721	0.0003795	0.001162	0.001442	0.0001306	0.001198	0.00019720
Phorate	0.00005936	0.0008650	0.001106	0.0001936	—	0.0003617	0.00008802
Carbophenothion	0.00005992	0.001116	0.0002642	0.0009956	—	—	0.0040020

[1]Sarup *et al*, (1967) [2]Sarup *et al*, (1966) [3]Sarup *et al*, (1964) [4]Sarup *et al*, (1961) [5]Jotwani *et al*, (1960) [6]Sarup *et al*, (1969) [7]Sarup *et al*, (1969)

—denotes that the pesticides were not tested.

The figures in parentheses are the LC_{50} values of different pesticides for *A. craccivora* infesting cowpea (Sarup *et al*., 1960)

5

terrestrial and aquatic plants to some pesticides

pea	Relative resistance*						
Aphis craccivora[7]	*Myzus persicae*	*Brevicoryne brassicae*	*Dactynotus carthami*	*Rhopalosiphum maidis*	*Aphis gossypii*	*Lipaphis erysimi*	*Aphis*** *craccivora*
0.0003017	1568.72	290.79	718.05	—	—	203.50	48.50
—	43.54	10.73	43.95	—	—	19.23	—
0.006797	3.17	16.90	6.03	—	—	0.57	0.28
—	High	1.85	1.72	—	—	0.17	—
0.0006759 (0.0005546)	1823.43	8101.09	359.71	13.70	65.09	192.13	79.82 (65.49)
0.02511 (0.02100)	26.46	23.22	13.15	1.84	2.71	0.41	2.54 (2.12)
0.001861 (0.002603)	4.54	144.08	10.93	4.89	5.43	1.29	2.39 (3.34)
0.04956 (0.02822)	1248.45	157.67	2051.76	87.65	49.04	55.84	146.58 (83.47)
0.01044 (0.002029)	859.59	118.05	371.33	—	274.02	108.22	51.08 (9.93)

—	4.24	6.48	18.59	—	5.54	0.21	—
(0.017790)							(0.41)
0.003859	105.78	72.02	6.96	—	106.57	30.30	38.44
0.00007150	2.20	6.75	8.38	0.76	6.96	1.15	0.41
(0.0007293)							(4.24)
0.000007319	14.57	18.63	3.26	—	6.09	1.48	0.12
0.001764	18.62	4.41	16.61	—	—	66.79	29.44

$$\text{*Relative resisnance} = \frac{LC_{50}\text{ value of a pesticide for a particular terrestrial aphid species}}{LC_{50}\text{ value of the same pesticide for } R.\ nymphaeae \text{ infesting aquatic } singhara \text{ plant}}$$

**Values of relative resistance for *A. craccivora* infesting cowpea are given in parentheses.

TABLE 6

Values of LC_{50} of different insecticides tested against *L. erysimi* (reared on mtstard) and their ratios together with 't' values for testing the differences in Log LC_{50} values

Log LC_{50} ± S.E.	LC_{50}	Insecticide	Log LC_{50} ± S.E.	LC_{50}	Ratio	't' values
2.0232 ± 0.6076	0.00003198	Phosphamidon	1.3275 ± 0.09031	0.00002125	0.66	1.132
1.6728 ± 0.2038	0.00004708	Dimethoate	1.5427 ± 0.11320	0.00003489	0.72	0.601
1.7445 ± 0.2333	0.00005552	Methyl parathion	1.8683 ± 0.13860	0.00007384	1.32	0.456
2.2951 ± 0.2019	0.00019720	Ethyl parathion	2.0572 ± 0.07827	0.00011410	0.57	1.098
2.8884 ± 0.2744	0.00077290	Endrin	2.9181 ± 0.12720	0.00082800	1.07	0.098
3.0029 ± 0.2136	0.00100700	Lindane	3.3970 ± 0.08504	0.00249500	2.47	1.714
3.0286 ± 0.1372	0.00106800	Malathion	2.6306 ± 0.07028	0.00042720	0.40	2.582**
3.2113 ± 0.4057	0.00162700	Carbaryl	3.5795 ± 0.09264	0.00379700	2.33	0.885
3.4832 ± 0.1705	0.00304200	Endosulfan	3.3282 ± 0.07543	0.00212900	0.69	0.831
3.6121 ± 0.0725	0.00409400	p,p' DDT	3.9467 ± 0.06232	0.00884500	2.16	3.500*
4.1421 ± 0.1372	0.01380000	Nicotine sulphate	3.9922 ± 0.10520	0.00982200	0.71	0.855
Sarup *et al.* (1969)†						

* Significant at 1 % level.

** Significant at 5 % level.

† Experiments were conducted in 1967.

$$\text{Ratio} = \frac{LC_{50} \text{ of a particular insecticide for } L.\ erysimi \text{ determ'ned in the present investigation}}{LC_{50} \text{ of the same insçticide for } L.\ erysimi \text{ worked out earlier †.}}$$

in relation to *D. Carthami* as compared to 1 : 388 in the case of endosulfan (Sarup *et al.*, 1965). Alcoholic extract of neem seed cake exhibited some degree of aphicidal activity against *R. nymphaeae* with an LC_{50} value of 0.0461 (Goyal *et al.*, 1971).

(g) Periodical checking of susceptibility level of aphid species

A comparison of LC_{50} values of different insecticides for *L. erysimi* after a two year period showed that the concentrations of lindane, carbaryl, p-p' DDT, methyl parathion and endrin increased 1.07 to 2.47 times (Table 6). In view of the decrease in toxicity of the above insecticides, it has been suggested that the LC_{50} values should be determined periodically, in order to detect any possible development of resistance in *L. erysimi* (Abhayankar and Sarup, 1970).

(h) Safety margin of aphicides for Coccinella septempunctata

Selective toxicity of aphicides to aphid pests and their safety for the adults and developing stages of the important predator, *C septempunctata* are two essential criteria for an integrated control schedule programme. Although organophosphates are effective aphicides, yet some members of the group are toxic to the predator also. This limitation is generally observed in the case of chlorinated hydrocarcarbons and botanicals. It has been reported (Singh *et al.*, 1978) that the least toxic insecticides against the grubs of *C. septempunctata* were aphidan, endosultan and nicotine sulphate, which give less than 50 % mortality even at 1.0 % concentration (Table 7). A comparison of relative resistance values of the grubs and adults of the predator in relation to important aphid pests indicate that endosulfan, lindane and aphidan have a very safety margin for both the stages of the predator, being at the same time effective and commonly used aphicides.

(i) Quality control of aphicidal formulation

It is evident from Table 7 that there is an appreciable variation in the LC_{50} values of technical and formulated insecticides against different aphid species. Thus, LC_{50} values of technical formothion (0.022) and endosulfan (0.003) against *L. erysimi* increased to 0.007 and 0.006 respectively in the case of formulated emulsion concentrates. The formulated products are accordingly three times less toxic to the aphid species than

TABLE

Values of LC_{50} and relative
C. septempunctata and

Insecticides	LC_{50} values for			
	Grub of *C. septempunctata*	*L. erysimi*	*D. carthami*	*A. craccivora*
Phorate	0.000015	0.000088	0.000194	0.000007
Phosphamidon	0.000230	0.000032	0.000401	0.000028
Diazinon	0.000977	0.001030	0.002004	0.000550
Malathion	0.001020	0.09068	0.001528	0.000344
Formothion	0.001380	0.001828	—	0.000624
Phenthoate	0.001663	—	—	0.006074
Methyl parathion	0.001945	0.000055	—	0.000088
Ethyl parathion	0.002818	0.000197	0.001442	0.000071
Fenitrothion	0.006412	—	—	0.000405
Orthodibrom	0.015130	0.003562	—	0.000144
Dichlorvos	0 015850	0.001059	0.021320	0.000192
Rotenone	0.070530	0.000304	0.000694	—
Phosval	0.076370	—	—	—
Trichlorphon	0.297800	0.005198	—	0.015220
Lindane	0.377580	0.001037	0.001861	0.001861
p,p' DDT	0.452100	0.004094	0.129900	0.02511
Aphidan	>1.0%	0.000449	—	0.001839
Endosulfan	>1.0%	0.00304	0.000699	0.003359
Nicotine sulphate	>1.0%	0.013800	0.14570	0.006797
Sarup *et al.*, (1969 a)	Sarup *et.al.*, (1964)		Sarup *et al.*, (1969b)	Jotwani *et al.*, (1960)

—denotes insecticides not tested.

7

resistance for the grub of different aphid pests.

	Relative Resistance (RR)*			
A. gossypii	*L. erysimi*	*D. carthami*	*A. craccivora*	*A. fossypii*
0.000362	0.17	0.07	2.14	0.04
—	7.19	0.57	8.21	—
0.007568	0.95	0.49	1.78	0.13
0.001705	0.95	0.67	2.96	0.60
—	—	—	21.00	—
—	—	—	0.27	—
—	35.36	—	22.10	—
0.001198	14.30	1.95	39.69	2.35
—	—	—	15.83	—
—	4.25	—	105.07	—
—	14.97	0.74	82.55	—
—	232.01	101.63	—	—
—	—	—	—	—
0.088160	57.29	—	19.57	3.38
0.004236	374.88	44.29	202.85	89.12
0.026810	110.430	3.48	180.05	16.86
—	□	—	□	—
0.010700	□	□	□	□
0.007006	□	□	□	□

□ Very high but cannot be calculated

$$*RR = \frac{LC_{50} \text{ value for predator grub}}{LC_{50} \text{ value for host aphid}}$$

the technical products. A Similar decrease in aphicidal activity of formulated endosulfan and dimethoate to the extent of 4 and 1.3 times respectively against *A. craccivora* as compared to their corresponding technical material was also observed. This indicates an appreciable effect of formulation on the aphicidal activity of toxic insecticides; and consequently, quality control of insecticidal formulations on the basis of their biological efficacy is not only necessary but indispensable.

TABLE 8

Toxicity of technical and formulated emulsion against aphid species

Insecticide	Aphid species	LC_{50}	
		Technical	formulated
Formothion	*L. erysimi*	0 002	0.007
Endosulfan	*L. erysimi*	0.003	0 006
Endosulfan	*A. craccivora*	0.002	0.008
Dimethoate	*A. craccivora*	0.0006	0.0008

Comparative toxicity studies of insecticides against various aphid species in relation to different parameters thus brings out the versatality of endosulfan, lindane and aphidan as effective aphicides. The results also reveal the indispensibility of quality control of aphicidal (insecticidal) formulations on the basis of their biological efficacy.

ACKNOWLEDGMENT

The authors are thankful to the Head of the Division of Entomology, I. A. R. I., New Delhi-110012, for providing necessary facilities and encouragement.

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VI. SHORT COMMUNICATIONS

BILATERAL ASYMMETRY IN THE MAIZE APHID, *RHOPALOSIPHUM MAIDIS* (FITCH)

INTRODUCTION

Variation in bilateral symmetry in *Aphis craccivora* Koch and *Rhopalosiphum padi* (Linnaeus) has been reported respectively by Goldberg (1944) and Ewing (1916). The present study deals with bilateral asymmetry in alate and apterous virginoparae of the maize aphid *Rhopalosiphum maidis* (Fitch) at Bhubaneswar in collections made in the three seasons, summer, rainy and winter of 1975-76.

AMALYSIS OF DATA

Length of six important morphological characters of taxonomic importance, e. g., antenna, processus terminali, Base VI of antenna, segment III of antenna, hind tarsus II and cornicle of left and right sides of *R. maidis* of at least twenty specimens collected in each of the three seasons are presented in tables 1-3.

An analysis of data presented in tables 1-3 brings out the following interesting freatures.

1. In *R. maidis* bilateral differences occur both in the alate and apterous virginoparae in all the three seasons, with regard to the antenna, that is, total length, base VI and of processus terminalis, due to longer growth of these parts only on the right side.

2. Bilateral differences does not occur with regard to the length of hind tarsus II and cauda, although Goldberg (2944) reports bilateral differences with regard to cornicle in *A. craccivora*.

3. Length of segment III of antenna is longer in the alatae on the left side in the rainy season only, while in the other two seasons no variation in bilateral symmetry occurs in respect of this character.

4. Length of segment III of antenna is longer in the apterous forms on the right side in the rainy season while, in the winter, the reverse is the case, the length on the left side being longer, and in the summer measurement of both the sides is the same.

TABLE 1

Length in mm of important morphological characters of left and right sides of *Rhopalosiphum maidis* collected on *Zea mays* during summer season (March, 1975 to June, 1975).

Character (in length)	Apterous		Alate	
	Left side	Right side	Left side	Right side
Antenna	0.742	0.763	0.938	0.969
Processus terminalis	0.240	0.254	0.303	0.325
Base VI of antenna	0.079	0.086	0.098	0.106
Segment III of antenna	0.201	0.201	0.252	0.252
Hind tersus II	0.083	0.083	0.084	0.081
Cornicle	0.175	0.175	0.149	0.149

TABLE 2

Length in mm of important morphological characters of left and right sides of *Rhopalosiphum maidis* (Fitch) collected on *Zea mays* during rainy season (July, 1975 to October, 1975).

Character	Apterous		Alate	
	Left side	Right side	Left side	Right side
Antenna	0.882	0.897	0.937	0.956
Processus terminalis	0.324	0 338	0.308	0 322
Bast VI of antenna	0.105	0.110	0.098	0 108
Segment III of antenna	0.301	0.298	0.245	0.252
Hind tarsus II	0.101	0.108	0.082	0 082
Cornicle	0.244	0.244	0.127	0.127

TABLE 3

Length in mm of important morphological characters of left and right sides of *Rhopalosiphum maidis* (Fitch) collected on *Zea mays* during winter season (November, 1975 to February, 1976).

Character	Apterous		Alate	
	Left side	Right side	Left side	Right side
Antenna	1.290	1.350	1 703	1.748
Processus terminalis	0.424	0.465	0.350	0.380
Segment III of antenna	0.353	0.360	0.252	0.252
Base VI of antenna	0 136	0.148	0.105	0.120
Hind tarsus II	0.154	0.157	0.145	0.154
Cornicle	0.259	0.259	0.196	0.196

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The Aphids : 370.375

ON THE FEMUR OF *APHIS GOSSYPII* GLOVER

INTRODUCTION

Aphis gossypii Glover is a polyphagous plant lice exhibiting a great range of variation in colour and size of the body. Cultures of the aphid species were maintained on the brinjal plant, *Solanum melongena* in different months of the year and the femur measured in order to find out if any significant statistical difference exists in the length.

MATERIALS AND METHODS

Alate and apterous virginoparae of *A. gossypii* were collected on brinjal in July through December 1974 and in January-February, 1975. Specimens were preserved in 70 % alcohol with a little lactic acid. Permanent slides were prepared in balsam and measurements of the femur were taken at least of fifteen specimens of each morph in each month. Collection of specimens in the summer months viz., March-June was negligible. Standard deviations and 't' values were calculated for each month separately and for the different seasons as well for comparing dimorphism.

Formulae used were as follows :—

(i) S. D. (standard deviation) $= \sqrt{\dfrac{(\bar{x} \sim x)^2}{n-1}}$

Where = Sum

$\bar{x}$ = mean of a month's observation

x = individual character

n = number of observations

~ difference

(ii) students 't' test

$$t = (\bar{x}_1 - \bar{x}_2) \sqrt{\frac{N_1 N_2}{N_1 + N_2}}$$

$$\sqrt{\frac{(N_1 - 1) S_1^2 + (N - 1) S_2^2}{N_1 + N_2 - 2}}$$

When 't' = Significance value (for comparison with calculated value) of 't' at 28° freedom.

x_1 = of 1st sample

x_2 = Mean of 2nd sample

N_1 = Number of observation of 1st sample

N_2 = Number of observation of 2nd sample

S_1 and S_2 = Standard deviations of 1st and 2nd samples respectively.

TABLE 1

Biometrics of femur of apterous *Aphis gossypii* Glov., reared on brinjal, *Solanum melongena* (based on measurements in mm. of 15 specimens for each month)

Months	Fore leg		Mid leg		Hind leg	
	Femur	Total Foreleg	Femur	Total Midleg	Femur	Total Hindleg
July, 1974	0.225	0.914	0.253	0.994	0.336	1.266
August, 1974	0.232	0.876	0.229	0.896	0.308	1.174
September, 1974	0.265	0.992	0.274	1.062	0.366	1.358
October, 1974	0.247	0.929	0.256	0.990	0.336	1.267
November, 1974	0.257	0.980	0.266	1.044	0.356	1.316
December, 1974	0.281	1.062	0.298	1.131	0.398	1.451
January, 1975	0.207	0.785	0.205	0.819	0.277	1.024
February, 1975	0.285	1.041	0.296	1.101	0.394	1.422
Range of variations in mm	0.168-0.392	0.651-1.248	0.154-0.350	0.672-1.271	0.203-0.469	0.798-1.680
Mean in mm	0.249	0.947	0.259	1.004	0.346	1.286
S. D.	±0.029	±0.089	±0.030	±0.097	±0.043	±0.105

TABLE 2

Biometrics of femur of alate *Aphis gossypii* Glov., reared on brinjal, *Solanum melongena* (Based on measurements in mm. of 15 specimens in each month)

Months	Fore leg		Mid leg		Hind leg	
	Femur	Total Foreleg	Femur	Total Midleg	Femur	Total Hindleg
July, 1974	0.288	1.070	0.242	1.040	0.344	1.330
August, 1974	0.308	1.166	0.271	1.137	0.381	1.433
September, 1974	0.305	1.134	0.258	1.096	0.364	1.374
October, 1974	0.314	1.153	0.260	1.092	0.364	1.374
November, 1974	0.311	1.172	0.263	1.136	0.380	1.433
December, 1974	0.305	1.103	0.261	1.046	0.360	1.349
January, 1975	0.278	1.033	0.299	9.979	0.320	1.249
February, 1975	0.292	1.087	0.252	1.058	0.355	1.355
Range of variations in mm.	0.210-0.378	0.849-1.316	0.196-0.350	0.815-1.346	0.273-0.434	1.036-1.694
Mean in mm.	0.300	1.114	0.254	1.073	0.359	1.364
S. D.	±0.032	±0.086	±0.023	±0.131	±0.026	±0.084

DATA AND ANALYSIS OF DATA

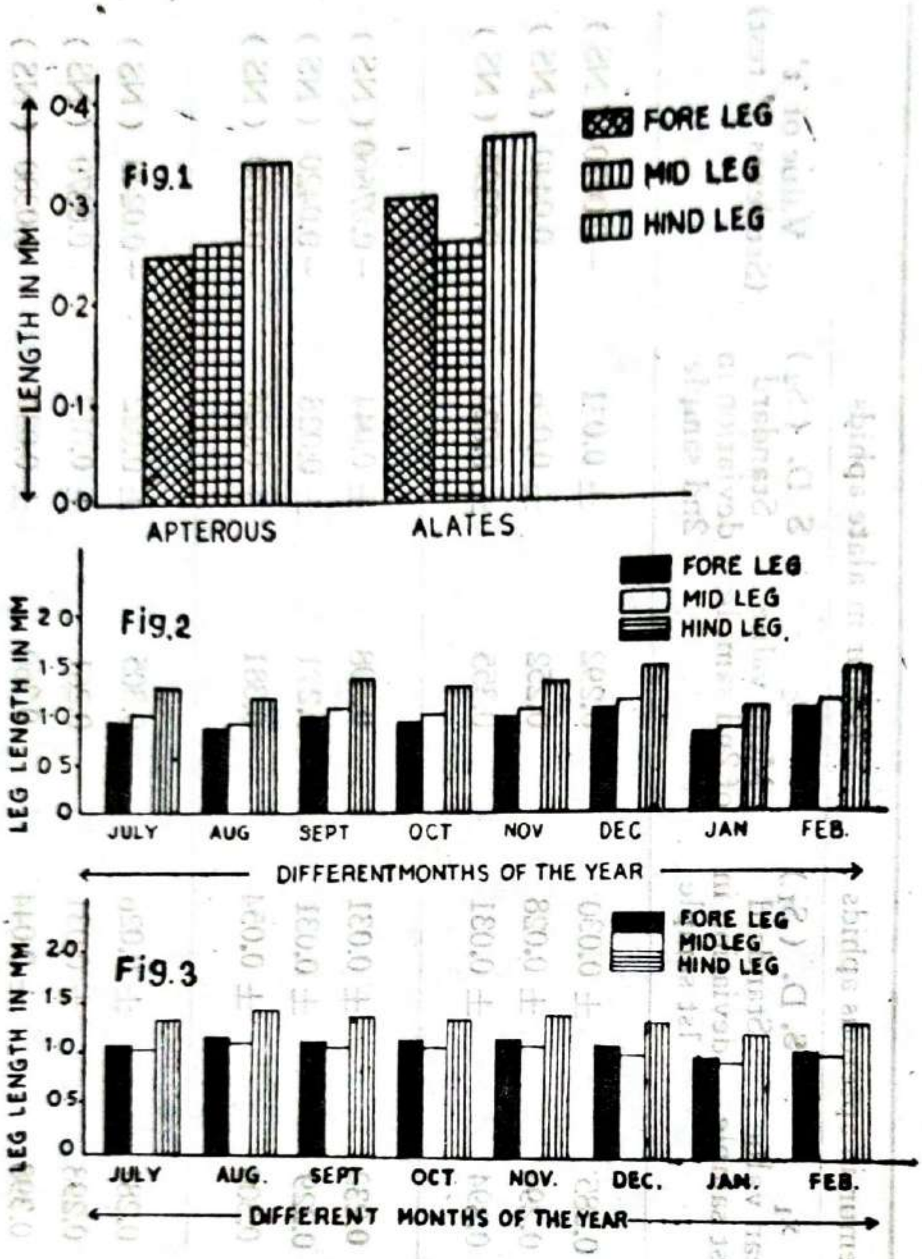
The data obtained are presented in Tables 1-3. An analysis of results shows that the femur and total length of the mid leg of alatae are the shortest, while in the apterae the and total length of the foreleg femur are the shortest (Figs. 1-2). However, when students 't' test is applied, the difference appears to be of no statistical significance.

TABLE 3

Seasonal significance of femur variations in apterous and alate aphids of *Aphis gossypii* Glover reared on brinjal, *Solanum melongena* (Number of observations in each case = 15).

Different seasons / months		Femur in apterous aphids		Femur in alate aphids		Value of 't' (Students 't' test)
		$\bar{x}_1$ Mean value of 1st sample	S. D. (S_1) Standard deviation in 1st sample	$\bar{x}_2$ Mean value of 2nd sample	S. D. (S_2) Standard deviation in 2nd sample	
Spring	Fore leg	0.285	± 0.030	0.292	± 0.031	−0.0070 (NS)
(February, 1975)	Mid leg	0.296	± 0.028	0.252	± 0.026	0.0440 (NS)
	Hind leg	0.394	± 0.031	0.355	± 0.024	0.0390 (NS)
Rains	Fore leg	0.232	± 0.031	0.308	± 0.044	−0.07660 (NS)
(August, 1974)	Mid leg	0.229	± 0.031	0.271	± 0.028	−0.0420 (NS)
	Hind leg	0.308	± 0.054	0.381	± 0.026	−0.0730 (NS)
Winter	Fore leg	0.281	± 0.026	0.305	± 0.022	−0.0240 (NS)
(December, 1974)	Mid leg	0.298	± 0.031	0.261	± 0.017	0.0370 (NS)
	Hind leg	0.398	± 0.044	0.360	± 0.030	0.0380 (NS)

(NS = Not significant at 5 % level)



Figs. 1-3. Variation in the length of legs of apterous and alate virginoparae of *Aphis gossypii* Glov.

ACKNOWLEDGMENTS

Sincere thanks are due to Mr. A. K. Ghosh, Statistician C. R. R. I., Cuttack and Utkal University computer centre for kind help in the analysis of data. Thanks are also due to Director, College of Basic Science and Humanities as well as Dean, Research Wing, O. U. A. T., Bhubaneswar for providing facilities for the work to one of the authors (DKR).

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ON THE HAEMOCYTES OF FOUR SPECIES OF APHIDS

INTRODUCTION

Although our knowledge of insect haemocytes is very much restricted, of late Boiteau and Perron (1976) have described the haemocytes of the potato aphid, *Macrosiphum euphorbiae* (Thomas) and Behura and Dash (1979) of the maize aphid, *Rhopalasiphum maidis* (Fitch). In the present investigation, an attempt has been made to report a comparative study of the haemocytes of four species af aphids, viz: *Lipaphis erysimi* (Kalt.), *Pentalonia nigronervosa* Coq., *Macrosiphoniella sanborni* (Gill.) and *Aphis craccivora* Koch.

MATERIALS AND METHODS

Adult apterous virginoparae of *L. erysimi*, *P. nigronervosa*, *A. craccivora* and *M. sanborni* were collected on radish (*Raphanus sativus*), banana (*Musa* sp.), bean (*Dolichus lablab*) and chrysanthemum (*Chrysanthemum sp.*) plants respectively during the winter of 1977. The blood cells were studied following the techinque of Sarkaria *et al* (1951). As far as possible, the terminology used by Romoser (1973) has been adopted in the present description. The investigation was carried out in the laboratory at a temperature $32 \pm 3°C$ and $60 \pm 2\%$ mean relative humidity.

OBSERVATIONS

The following types of haemocytes are noticed in the haemolymph of the four species of aphids.

1. Prohaemocytes—Prohaemocytes occur in all the four species. They are spherical in shape with a large nucleus which almost covers the entire cell leaving a scanty amount of cytoplasm at the periphery (Fig. 1a). The diameter of the cells in different aphids varies between 3.1 and 6.3 μ (Table 1).

2. Plasmatocytes—This cell type (Fig. 1b) is of common occurrence in all the four species of aphids. Generally the cell is circular in shape, the nucleus is small and centrally placed. The diameter of the cells varies between 3.0 and 4 0 μ (Table 1).

TABLE 1

Diameter (in micra) of different types of haemocytes of four species of aphids.

	Phohaemocyte		Plasmatocyte		Podocyte		Granular haemocyte	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Macrosiphoniella sanborni	3.6—6.3	4.6	3.0—3.7	3.1	2.8—3.5	3.1	—	
Lipaphis erysimi	3.6—4.6	3.8	3.1—3.6	3.2	1.8—2.7	2.5	—	
Pentalonia nigronervosa	3.2—4.4	3.7	3.1—4.0	3.4	—		2 2—2.7	2 4
Aphis craccivora	3.1—4.0	3.4	3.1—3.6	3.2	—		2.4—3.0	2.6

Besides the circular plasmatocytes, some spindle shaped plasmatocytes (Fig. 1c) are also found in the haemolymph of *M. sanborni*, *A. craccivora* and *L. erysimi* the length of which are 4.5, 5.4 and 4.1 μ respectively. These cells are nothing but an another form of plasmatocyte. They are elongated cells with the two ends almost tapering, the ends being blunt. The nucleus is small and lies at the centre of the cell.

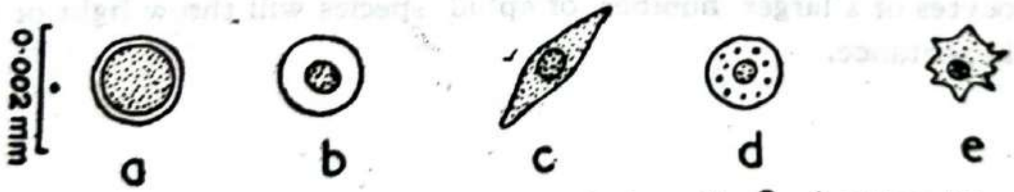

Fig.1 - *Types of haemocytes in aphids.* a - *Prohaemocyte.* b - *Plasmatocyte*, c - *Spindle shaped plasmatocyte*, d - *Granular haemocyte*, e - *Podocyte*

3. Podocytes—These cells (Fig. 1a) are irregular in shape, giving out a number of projections or pseudopodia. The nucleus is small lying either at the centre or at one side of the cell. Podocytes occur in very small numbers in *M. sanborni* and *L. erysimi* only, their diameter being 3.1 and 2.5 μ respectively.

4. *Granular haemocytes*—These are irregular in shape, mostly circular with a small nucleus at the centre. The cytoplasm is composed of darkly stained, distinctly visible tiny granules (Fig. 1d). These granules almost fill the space between the nucleus and the cell membrane. Granular haemocytes are found only in the haemolymph of *P. nigronervosa* and *A. craccivora* and the diameter of the cells varies between 2.2 and 3.0 μ (Table 1).

DISCUSSION

Yeager (1945) described **32** types of haemocytes in insect haemolymph. Jones (1962) has recognised nine main types, viz., prohaemocytes, plasmatocytes, podocytes, granular haemocytes, oenocytoids, spherule cells, cystocytes, adipohaemocytes and vermiform cells. Boiteau and Perron (1976) found five types of haemocytes in *M. euphorbiae*, viz., prohaemocytes, plasmatocytes, granular haemocytes, spherule cells and oenocytes. Behura and Dash (1979) noticed four types of haemocytes namely, prohaemocytes, plasmatocytes, podocytes and cystocytes in *R. maidis*. In the present investigation, the haemolymph of all the four species of aphids, viz., *P. nigronervosa, L. erysimi, M. sanborni* and *A. craccivora* has a predominance of two types of cells, the prohaemocytes and plasmatocytes. Excepting *P. nigronervosa* all the remaining three aphid species have a few spindle-shaped plasmatocytes. Granular haemocytes are seen only in *P. nigronervosa* and *A. craccivora* while podocytes are noticed only in *M. sanborni* and *L. erysimi*. 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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The Aphids : 380.383

A STUDY ON THE PATTERN OF HONEY-DEW PRODUCTION IN THE GREEN PEACH APHID, *Myzus persicae* Sulzer*

INTRODUCTION

Among the type of injuries to plants by aphids the deposit of honeydew excretion on leaves is not less important as it favours the development of black sooty mould on the leaves and thus reduces the leaf assimilative area exposed to the sun for photosynthesis. Besides, on tobacco and leafy vegetables, where the economically important (edible) parts are leaves, the market value is very much reduced due to appearance of sooty mould on them. Hence a basic study was taken up to study the pattern of excretion in the green peach aphid, *Myzus persicae* Sulzer which is a serious pest of tobacco and other cole crops and results of observations are reported hereunder.

MATERIALS AND METHODS

The frequency of excretion in *M. persicae* was studied on chillies (*Capsicum annuum* L.) under glasshouse conditions. Fresh first instar nymphs were introduced individually inside a leaf clip-on cage fixed on the under-surface of the leaves and held vertically by means of a support so that the droplets excreted by the aphid fell on the fitler paper strip which was introduced in the place of the lid to collect the excretions. The filter paper were changed at four intervals. The process was continued for 24 h for each instar and thus the excretion of four instars were observed.

The honeydew collected filter papers were then sprayed with Ninhydrin 0.2 % in 95 per cent Butanol (200 mg in 100 ml of Butanol) and dried in the hot air oven to show up the honeydew droplets by way of purple to violet spots (due to the presence of amino acids). The number of droplets in a particular filter paper strip revealed comparatively the number of droplets excreted by that particular instar over a constant period.

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* **Forms part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M. Sc. (Ag.) Degree by S. R.**

Studies were also carried out to test any variation in the rate of excretion of the aphid when reared on different host plants. Five host plants viz., brinjal, cabbage, cauliflower, chillies and tobacco were used and the rate of excretion was observed as per the procedures given above.

RESULTS AND DISCUSSION

Significant differences were noticed in the frequency of excretion between instars and the results are given in Tabl 1. The second instar nymphs excreted more number of droplets in four h period (6.50 droplets) followed by first (6.41 droplets), third (6.17 droplets) and fourth instars (5.78 droplets). However, there was no significant difference between the first and second instars. Kunkel and Hertel (1976) made similar

TABLE 1

Honey-dew excretion of *M. persicae* fed on chilli during different parts of the day

Sl No.	Period of feeding	Mean number of droplets excreted by different instars				Mean
		I	II	III	IV	
1.	6 a.m. to 10 a.m.	6.5	6.6	6.2	6.0	6.33
2.	10 a.m to 2 p.m.	7.0	6.7	6.3	6.1	6.53
3.	2 p.m. to 6 p.m.	6.8	7.7	6.7	6.0	6.80
4.	6 p.m. to 10 p.m.	6 2	6.3	6.1	5.5	6.03
5.	10 p.m. to 2 a.m.	6.0	5.7	5.8	5.4	5.73
6.	2 a.m. to 6 a m.	6.0	6.0	5.9	5.7	5.90
		6.41	5.50	6.17	5.78	

Comparison of significant effects :

	Level of significance	C. D. (P = 0.05)
Between instars	P = 0.01	0.28
Between periods	P = 0.01	0.34
Instar × Period	N. S.	—

TABLE 2

Honey-dew excretion of *M. persicae* fed on different host plants in a day.

Sl. No.	Host plants	Mean number of droplets excreted by each instar				Mean
		I	II	III	IV	
1.	Brinjal	37.6	37.5	37.3	35 9	37.08
2.	Cabbage	35.0	36.6	36.1	33.0	35.18
3.	Cauliflower	36.3	37.7	36.4	32.3	35.68
4.	Chillies	38.5	39.0	37.0	34.7	37.30
5.	Tobacco	37.5	37.4	35.7	33.7	36.03
	Mean	36.98	37.64	36.50	33.92	—

Comparison of significant effects :

	Level of significance	C. D. (P = 0.05)
Between host plants	N. S.	—
Between instars	P = 0.01	1.79
Host plant × Instar	N. S.	—

studies on *M. persicae* with artificial diets and found the third instar excreting more frequently than the second instar. The aphids excreted more during the day than during the night. The frequency of excretion attained a peak between 2 p. m. and 6 p. m. and was minimum between 10 p. m. and 2 a. m. This might be due to the higher light intensity and higher temperature which prevailed between 2 p. m. and 6 p. m. than during the rest of the day (Kunkel and Hertel, *loc. cit.*).

Among different host plants tested higher excretion rate was observed on chillies, on which the aphid excreted 37.3 times a day, followed by brinjal, tobacco, cauliflower and cabbage (Table 2.). However, these differences were not found to be significant statistically.

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The Aphids : 384-386

RELATIVE OCCURRENCE OF COLOURED FORMS IN *Myzus persicae* Sulzer IN TAMIL NADU*

INTRODUCTION

The Green peach aphid *Myzus persicae* Sulzer is a very destructive species as it is able to transmit over two hundred virus diseases of plants of 30 different families (van Emden *et al.*, 1969). It is a serious pest of several important crops and in view of its host range, it is posing a big threat to the farmers. In Tamil Nadu it attacks several crops including brinjal, cabbage, cauliflower, chillies and tobacco and it occurrs in different colour forms. The occurrence of different colour forms was reported earlier by Tanama (1957), Valencia (1976) and Ueda and Takada (1977) from abroad. Hence a survey was made in this area to find out the presence of different coloured forms of this aphid

MATERIALS AND METHODS

To study the colour forms present in this region, samples of *M. persicae* were collected on brinjal, cabbage, cauliflower, chillies and tobacco from the fields in and around Coimbatore and Nilgiris during respective cropping seasons in 1977-78. The percentages of yellow, green and red forms were worked out by taking samples from 10 randomly selected plants and by recording the total number of aphids and the number of yellow, green and red coloured aphids. To confirm the identity irrespective of colouration, each sample was processed and permanent slides were prepared in carbol-chloral medium and identified by the characters described by David (1954).

RESULTS AND DISCUSSION

Variations in the colour of the aphid was noted on all host plants (Table 1). Yellow form dominated the populations on tobacco (98.12 %), brinjal (96.98 %) and chillies (94.43 %) while green forms dominated on

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* Forms of part of the thesis submitted to the Tamil Nadu Agricultural University for the award of M. Sc. (Ag.) degree by S. R.

cauliflower (78.52 %) and cabbage (69.24 %). Red form also occurred on tobacco, brinjal and chillies but in very few numbers while being completely absent in cabbage and cauliflower. Similarly green form was completely absent on brinjal, chillies and tobacco.

TABLE 1

Relative abundance of colour forms of *Myzus persicae* in Tamil Nadu

Sl. No.	Host plant	Percentage of		
		Yellow forms	Green forms	Red forms
1.	Brinjal	96.98	0.0	3.2
		[80.95]	[3.72]	[10.03]
2.	Cabbage	30.76	69.24	0.0
		[33.67]	[56.34]	[3.72]
3.	Cauliflower	21.48	78.52	0.0
		[27.61]	[62.39]	[3.72]
4.	Chillies	94.43	0.0	5.57
		[76.42]	[3.72]	[13.58]
5.	Tobacco	98.12	0.0	1.88
		[82.22]	[3.72]	[7.78]
	Mean	68.35	29.55	2.09
		[59.99]	[25.98]	[7.77]

[Figures in parantheses are transformed values]

	Level of significance	C. D. (P = 0.05)
Between forms	P = 0.01	1.18
Form × host plant	P = 0.01	26 5

Earlier Brain (1942) stated that colour variation in this species of aphid may be due to some biotypical characters. But later workers suggested that this variation may be due to the influence of the host plant (Valencia, 1976; Ueda and Takada, 1977). Ueda and Takada (*loc. cit.*) reported that proportion of colour forms occcrring on potato and radish varied between host plants and this might be due to nutritional variation between the host plants. Interestingly, our investigations showed that green form was abundant in hilly tracts on cabbage and cauliflower while yellow forms were predoninant in the plains on all host plants.

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ON THE HAEMOLYZING EFFECT OF THE LOTUS APHID *RHOPALOSIPHUM NYMPHÆÆ* (LINN.)

INTRODUCTION

As early as 1915 the German scientist, Dewitz reported that aphids occurring on the plant *Pelargonium*, contained a substance called "aphidolysin" which is toxic to ox blood. The present paper deals with some experimentats made with the toxin present in the lotus plant lice, *Rhopalosiphum nymphaeae* (Linn.) on cow blood.

MATERIALS AND METHODS

Half a gram by weight of freshly collected adult apterous virginoparae of *R. nymphaeae* from lotus plant, *Nelumbium speciosum* was taken and slowly made into a paste in 2.5 ml of physiological salt solution and an equal amount of glycerine. The mixture was kept in the ice chest of a refrigerator for twenty-four hours before it was filtered to form the stock solution of aphid extract. Five mililitres of cow blood was taken and mixed with 95 ml of physiological salt solution to prepare a 5 % blood solution. It was centrifuged, during which process the liquid was replaced 3 to 4 times by salt solution. Four concentrations of the above aphid extract (0.08, 0.04, 0.02 and 0.01) were prepared by diluting 0.08, 0.04, 0.02 and 0.01 ml of the stock solution of filtered aphid extract with 1 ml of physiological saline in four separate tubes. Tubes employed for serum investigation were used in the experiment. One ml of 5 % dilution of cow RBC was taken in each tube. Into four such tubes were added 1 ml of aphid concentrate of the dilutions mentioned above containing 8, 4, 2 and 1 mg of aphid matter respectively. To four other tubes containing 1 ml of 5 % dilution of cow RBC were added 1 ml of physiological saline to serve as control. The tubes were warmed at 37°C for 2½ hours, cooled and placed in the ice-chest of the refrigerator overnight to study the effect. The expriment was repeated at least three times.

RESULTS AND DISCUSSION

On examination of the experimental serum tubes it was noticed that the RBC in the tubes to which 0.08 and 0.04 ml of aphid extract had been added, were completely haemolyzed, while the tubes treated with 0.02 ml of aphid extract was only partially dissolved as a small proportion of undissolved RBC was noticed at the bottom of the tube. The RBC in the tube treated with 0.01 ml of aphid extract and in the control tubes remained undissolved. From the experiment, it is clear that a solution of 0.04 ml extract containing 4 mg of aphid matter can haemolyse completely the RBC present in 1 ml of 5 % blood dilution or 0.05 ml of pure cow blood.

Sachs (1902) reported that 0.56 gm of arachnolysin of the house spider, *Araneus diadematus* (Clerk) can haemolyze 1 litre of rabbit blood. Dowitz (1915) established that 40 gm of aphidolysin of plant lice of *Pelargonium* could haemolyze the same amount of ox blood. In the present investigation, we found that 1 gm of aphid matter will bring about complete haemolysis of R. B. C. present in 12.5 ml of cow blood or 80 gm of aphidolysin of *Rhopalosiphum nymphaeae* is enough to haemolyze 1 litre of cow blood.

Aphidolysin of the same species and of different species of aphids may differ according to the nature of host-plant. Quite likely the toxin lies dissolved in the haemolymph of the insect although the possibility of the toxin being secreted by any particular gland can not be discarded.

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The Aphids : 389-395

ON THE LIFE HISTORY AND HOST PREFERENCE OF THE BEAN APHID, *APHIS CRACCIVORA* KOCH*

INTRODUCTION

The bean aphid, *Aphis craccivora* Koch is a serious limiting factor in the cultivation of country beans and cow pea which constitutes an important vegetable in the diet of vegetarians. Madhya Pradesh has large acreages of nut, chick pea, pigeon pea, lentil and lathyrus of which the bean aphid is a potential pest. The pest is already known to have inflicted heavy damage to pea nut (Dorge *et al*, 1966; Shrivastava *et al*, 1965; Baketia *et al*, 1977) and pigeon pea (Waghmare, 1974) in the neighbouring states. Recently, the pest was reported to have assumed epidemic form on chick pea in some pockets of Bhopal district of M. P. Studies were initiated in 1975 to obtain information on the life cycle, host preferences, natural controlling agents and chemical control of the bean aphid.

MATERIALS AND METHODS

The life cycle of the bean aphid was studied in the laboratory on bean sprouts (*Dolichos lablab* var. JDL-44) at mean temperature of 31°C ± 1 and R. H. 91 % ± 1. Sexually matured female aphids were placed on bean sprouts and were allowed to multiply. As soon as a female laid nymphs they were picked up with the help of a fine camel hair brush and placed on the fresh bean sprouts kept in the petri dishes. The turgidity of the plants was maintained by rapping the basal cut end of the sprouts with moist cotton plugs. Observation was recorded every 24 hours when the insects were also supplied with fresh food. The duration of each developmental stage, its dimensions, morphological characters and the reproductive capacity of the female were recorded. Each set of the experiment was replicated 10 times and the mean so obtained is presented in Table 1.

* This research has been partially financed by a grant (No. FG.-III 545/IN-ARS-21) made by USDA, Agriculture Research Service, under PL-480.

TABLE 1

Life cycle and fecundity of the bean aphid, ***Aphis craccivora*** Koch on *Dolichos lablab* at 31°C ± 1 and R. H. 91 % ± 1

Developmental stage		Period in days		Dimensions in mm		
		Duration of each stage	Total duration	Body length	Body width	Antennal length
1. Nymph	1st instar	1.3		0.7 ± 0.01	0.2 ± 0.002	0.4 ± 0.001
	2nd instar	1.0		1.2 ± 0.01	0.5 ± 0.004	0.6 ± 0.01
	3rd instar	1.1	4.4	1.2 ± 0.02	0.6 ± 0.003	0.6 ± 0.003
	4th instar	1.0		1.4 ± 0.02	0.7 ± 0.01	0.7 ± 0.01
2. Adult	Prematuration	0.6		1.9 ± 0.01	1.0 ± 0.01	1.2 ± 0.005
	Reprod-phase	6.7	7.6			
	Post reprod. phase	0.3				
3. Total life span		12.0				

Fecundity of female aphid

Total nymphs laid	Daily mean	Nymphs laid per day	
		Max.	Min.
45.7	6 7	13.0	1.0

The host preference of the aphid was studied on the following seven hosts in the laboratory at the mean temperature of 32° ± 2°C and its relative humidity 94 ± 3 per cent.

1.	Cow pea, ***Dolichos lablab***	var. JDL-44.
2.	Country bean, ***Vigna sinensis*** Savl.	var-JDL Phillipines.
3.	Pigeon pea, ***Cajanus cajan*** Mislp	var-JDL Ujjain-7
4.	Pea nut, ***Arachis hypogea*** Linn	var-JDL Jyoti
5.	Pea, ***Pisum sativum*** Linn.	var-JDL Bonvella
6.	Chick pea, ***Cicer arietinum*** Linn.	var. JDL-44
7.	Lathyrus, ***Lathyrus sativus*** Linn.	var-JDL No. 9

Ten day old seedlings were used for feeding the aphids. In case of pigeon pea, in addition to the above, the flowering aud fruiting stages of the plans were also tested for preference.

The observations for growth and moulting were recorded every 24 hrs. Longevity and fecundity of the female aphid was also observed for each host plant. The sexually matured female aphid was released on the seedling of the desired host and the young nymph reproduced by this female were then removed every day with the help of a camel hair brush and released on the selected host. The food was changed every day. The nymphs of the required stage from the desired host were thus collected, preserved in 70 per cent alcohol, cleared in xylol and measured under the microscope. At least 10 insects were measured for each treatment, the data statistically analysed and are presented in Tables 2 and 3

RESULTS AND DISCUSSION

Life cycle of bean aphid : The matured female aphid lifts her posterior abdominal region and starts jerking. After a few seconds the posterior end of a nymph starts protruding. The mother continues jerking till the nymph is completely laid out while the nymph presses its legs against the surface of the host plant and tries to wriggle out of the mother's body. The complete process takes about 10 minutes. During the period of reproduction the interval between the birth of two nymphs varied from 20 minutes to 3 hrs. At the time of emergence the antennae and legs of the nymph remain closely pressed against the dorso-lateral and ventral side of the abdomen and the colour is transluscent, except the redish brown compound eyes. After about 5 minutes the

TABLE 2

Effect of different host plants on the development of the bean aphid, ***A. craccivora*** Koch.

Host plants	Developmental period in days	Longevity of adult in days	Fecundity of female (No. of nymps laid)
Cow pea seedling	4.3 (2.19)*	11.5 (3.40)	81.4 (8.96)
Bean seedling	4.5 (2.22)	09.2 (3.60)	67.4 (8.07)
Lathyrus seedling	5.8 (2.49)	07.8 (2.77)	30.5 (5.25)
Gram seedling	5.9 (2.52)	04.2 (2.15)	14.7 (3.86)
Pea seedling	5.9 (2.50)	04.0 (2.09)	16.2 (3.97)
Pigeon pea (flowering stage)	7.4 (2.58)	03.6 (1.98)	00.06 (0.97)
Pigeon pea (fruiting stage)	7.0 (2 52)	02.6 (1.67)	00.08 (0.93)
Pigeon pea seedling	0.0 (0.71)	— —	— —
Pea nut seedlings	0.0 (0.71)	— —	— —
C. D. at 5 per cent	0.20	0.42	0.12

* The values in the paranthesis are transformed by formula $\sqrt{x + 0.5}$

transparency gradually disappears, the body changes to light yellow and the apical part of the cornicles turn reddish brown. After 30 minutes the nymph starts walking and an hour later, it starts feeding.

TABLE 3

Effect of different host plants on the size of the bean aphid, *A. craccivora* Koch.

Host plants	Size of aphid in mm (length × width) instars				
	I	II	III	IV	Adults
Bean	0.31	0.54	0.85	1.79	2.46
Cow pea	0.27	0.51	0.82	1.75	2.41
Lathyrus	0.27	0.39	—	—	—
Chick pea	0.17	—	0.75	1.28	1.51
Lathyrus	—	—	—	1.20	1.44
Pea	0.15	0.33	0.66	1.18	1.34
Chick pea	—	0.30	—	—	—
Lathyrus	—	—	0.65	—	—
C. D. at 5 per cent	0.02	0.02	0.03	0.21	0.72

There are four nymphal instars lasting 1.3, 1.0, 1.1 and 1.0 days respectively. The total nymphal period is 4.4 days. Behura (1956) also recorded four nymphal moults in *A. craccivora*. Baketia and Sidhu (1977) however, reported 4-5 moults in bean aphids. The female aphid took 0.6 day to mature and laid nymphs parthenogenetically. During the entire reproductive period of 7.6 days, a single female produced 16 to 58 nymphs (mean 45.7). More than 70 per cent of nymphs were laid during the earlier 2-5 days. The maximum number of nymphs were laid on the second day. The fecundity of the female aphid gradually declined after the 5th day of reproduction. The post-reproductive phase lasted 0.3 days after which the female died.

Host preference: From Tables 2 and 3, it is apparent that the different host plants exert influence which was statistically significant on the development, body size, fecundity and longevity of the bean aphid. The aphids reared on cowpea and bean seedlings developed faster, were larger in size, reproduced more number of nymphs and the adults lived longer than on any other host. From amongst the various hosts tested, Bernardo (1969) reported garden bean (*D. lablab*) and Waghmare *et al* (1974) cow pea as the most preferred host of the bean aphid. This is in agreement with our findings. The seedlings of pea nut and pigeon pea were totally unfavourable for bean aphids as they could not develop on these hosts beyond the 2nd or 3rd instar stage. The flowering and fruiting stage of pigeon pea proved better than its seedling stage but as a whole the crop was unsuitable for the natural breeding of the aphids. The fact that *A. craccivora* is not an important pest of pea nut or pigeon pea in M. P. supports our conclusions. Baketia *et al* (1977) and Dorge *et al* (1966) found pea nut as the preferred host of bean aphid which is contrary to our findings. The difference, however, may arise due to the difference in the varieties viz., Jyoti (pea nut) and Ujjain-7 (pigeon pea) of the crops tested by us. The presence of different biotypes in the different regions of the country can not be ruled out.

Aphids fed on bean or cow pea developed faster, were of larger size, reproduced more nymphs and the adults lived longer than on other hosts. Pea nut and pigeon pea were totally unfavourable while lathyrus, chick pea and pea were hosts of intemediate nature.

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The Aphids : 396-400

EVALUATION OF CERTAIN SAFFLOWER CULTIVARS FOR RESISTANCE TO *DACTYNOTUS CARTHAMI* HRL.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is the best suited *Rabi* oilseed crop in dry land agriculture in India. It occupies an area of about 0.6 million hectares with a production of 0.13 million tonnes (Gregory *et al*., 1974). As this oil contains as high as 81 per cent linoleic acid as against 21 per cent in the groundnut oil, it is considered to be excellent for dietary use (Patil *et al*., 1974). India is the major safflower growing country in the world, but the production is appallingly low (195 kg/ha) as compared to other countries. The aphid *Dactynotus carthami* HRL is a major pest of safflower. It attacks the crop at the capsule formation stage. Due to constant desapping of juice the plants look sickly and the formation of capsules are arrested. This results in the low yield of the crop.

MATERIALS AND METHODS

In order to know the resistance of 9 safflower cultivars to *D. carthami* observations on various plant characters and aphid population were recorded from the coordinated varietal trial conducted at the Regional Research Station, Chiplima during *Rabi* 1978-79. This trial was conducted in a randomized block design with three replications. Each cultivar was grown in sub-plots of 25 sq. m. The row to row and plant to plant distances were maintained at 45 and 20 cm. respectively. Fertilizers were applied at the rate of 40 : 40 : 20 of N. P 205 and K_2 O / ha respectively. Twenty plants from each sub-plot were selected randomly and observations on various plant characters and aphid infestation were recorded from these selected plants. The incidence of aphid was taken at 80 days after sowing. While counting the number of aphids per plant, all the stages were taken into account which were dislodged from individual plants to a drawing sheet 15 × 20 cm and the dislodged aphids were counted. The average number of capsules / plant was taken 7 days before harvest.

To evaluate the relative efficacy of different insecticides for the control of the 3rd instar aphid nymphs, the bulk crop was thoroughly sprayed with specified insecticides, and the cut branches free from aphids were provided as food. 30 minutes after spraying. The nymphs were pre-conditioned for four hours before releasing them on the treated branches. In each petri dish 20 nymphs were released and each treatment was replicated thrice. Fresh food was supplied after twelve hours of feeding on the treated branches. Moribund insects were taken as dead. To prevent drying of the branches, the cut ends were plugged with small pieces of cotton soaked in water.

RESULTS AND DISCUSSION

It is evident from table 1 that the plant height in different cultivars varied from 56.3 to 76.6 cm. The plant heights in CTS 7218, CTS 7403 and CTS 7205 varied significantly from the varieties V-168 and V-673. The number of branches per plant, percentage of infested branches and the number of capsules per plant in different cultivars did not vary significantly. Aphid infested plants in different cultivars ranged from 38.9 to 68.9 per cent. The cultivars V-168 and CTS 7205 had 38.9 and 39.1 per cent aphid infested plants as compared to cultivars V-673 where it was 68.9 per cent. Initial infestation was confined to the terminal shoots only but later on these aphids migrated to the leaves and capsules. The aphid infested branches in different cultivars varied from 20.04 to 40.99 per cent. As high as 1053 number of aphids were recorded in the susceptible variety but the average number of aphids per plant ranged from 14.66 (CTS 7205) to 105.23 (V-83). The infested plants looked sickly and gradually dried up before the formation of the seeds. These symptoms were very clear in the non-spiny cultivar CTS 7403. The yield varied from 0.240 to 1.150 kg / sub-plot. Although there was significant variation in the aphid population in different cultivars, there was no significant variation in the yield. The variety S-144 which harboured comparatively lower number of aphids recorded the highest yield (table 1). The second best yield was obtained from the susceptible variety V-83. This indicates that the variety V-83 is a potential yielder but due to heavy attack of aphids the yield was reduced. Besides aphid infestation the yield difference may be due to the reproductive capacity of different cultivars as the number of capsules varies from variety to variety.

TABLE 1

Varietal response of different safflower cultivars to *Duetynotus carthami* infestation under natural infestation conditions (Rabi 1978-79).

Variety (V*)	Plant height (cm)	Number of branches per plant	Aphid infested plants (%)	Aphid infested branches (%)	Number of aphids / plant	Number of capsules / plant	Yield Kg / plot
V 168	56.3	4.4	38.9	27.76	28.66	5.7	0.62
S 144	62.3	5.4	50.8	28.93	34.83	10.8	1.15
V 83	60.6	5.5	61.9	40.99	105.23	8.9	0.75
V 673	58.7	4.8	68.9	45.65	99.33	8.3	0.54
CTS 7218	76.6	5.3	53.9	34.06	80.33	7.4	0.24
A 1	63.7	4.8	54.0	32.61	41.33	7.7	0.65
K 1	62.1	5.3	57.3	34.29	83.86	11.5	0.73
CTS 7403	73.5	6.8	49.3	28.41	76.33	10.3	0.49
CTS 7205	70.4	5.9	39.1	20.04	14.66	9.7	0.43
C. D at 5%	10.1	NS	7.4	NS	19.4	NS	NS

V*—variety number NS—Not significant.

TABLE 2

Relative efficacy of different insecticices against *Dactynotus carthami* HRL under laboratory conditions.

Name of the insecticide	Concentration	Percentage mortality of aphids after feeding for (mean of 3 replications)	
		24 hours	48 hours
Quinalphos 25 EC	0.05	78.33	85.00
Monocrotophos 40 EC	0.05	96.66	100.00
Dimethoate 30 EC	0.05	80.00	85.00
Phosphomidan 100 EC	0.05	88.33	91.66
Malathion 50 EC	0.05	78.33	81.66
Methyl Demeton 25 EC	0.05	98.33	100.00
Fenitrothion 50 EC	0.05	68.33	71.66
Carbaryl 50 WP	0.10	53.33	60.00
Control	—	8.33	11.66
CD at 5 %		8.75	5.30

Out of 8 insecticides tested methyl demeton and monocrotophos both at 0.05 per cent concentration killed 98.33 and 96.66 per cent aphids as compared to 8.33 per cent kill in the untreated check at 24 hours after feeding. Carbaryl 0.1 per cent was found least effective which could kill only 53.33 per cent aphids. The mortality was further increased after 48 hours of treatment. Methyl demeton and monocrotophos could kill 100 per cent aphids followed by demecron, quinolphos and dimethoate where the mortality varied from 80.00 to 88.33 per cent.

ACKNOWLEDGMENT

The author is grateful to Dr. R. N. Mohanty, Associate Director of Research, Regional Research Station, Chiplima for providing necessary facilities and to Sri S. Ram, Jr. Entomologist for his help during the course of investigation.

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ON THE HOST PREFERENCE OF APTEROUS VIRGINOPARÆ OF *APHIS GOSSYPII* GLOVER

INTRODUCTION

Aphis gossypii Glover is polyphagous infesting about 125 plants. It is found all over the world, and all over India including the hills upto 7,000 feet throughout the year on different host plants (Behura, 1963). The ability of this pest to transmit, numerous plant viruses makes it one of the most economically important aphids (Behura, 1978).

The present paper embodies results of our investigations on the host preference of *A. gossypii* employing five plants, viz., *Hibiscus rosasinensis, Solanum melongena, Psidium guajava* and *Gossypium* sp.

MATERIALS AND METHODS

Adult apterous virginoparae of *A. gossypii* were collected on *H. rosasinensis* in the field and maintained in the laboratory at 27 ± 3°C and 60 ± 5 % RH on the leaves of the same host. The newly born Ist instar nymphs immediately after birth were transferred to clean glass petri dishes with moist blotting paper and provided with the leaves of any one of the four host plants, namely, *H. rosasinensis*, *S. melongena*, *P. guajava* and *Gossypium sp.* Observations were noted on the development, fecundity and longevity of the aphid on the leaves of different host plants. A minimum of ten adults were reared on each host plant separately from the first instar stage till they attained adulthood.

RESULTS AND DISCUSSION

The data for developmental period, fecundity and longevity of the aphid species on the four different host plants are presented in Table 1.

It was found that the minimum developmental period was 123 hours on *P. guajava* while the maximum was 181 hours on *H. rosasinensis.* Fecundity was highest, 28, on *H. rosasinensis* while lowest, 14 on *P. guajava*. Longevity was maximum on *H. rosasinensis* and minimum on *P. guajava.*

Thus it appears that although the developmental period is longest on *H. rosasinensis*, it is the most preferred host plant so far as longevity and fecundity are concerned.

TABLE 1

Development, fecundity and longevity of apterous forms of *Aphis gossypii* on different host plants.

Host plant	Developmental period in hours	Total No. of nymphs produced	Life span in days
Hibiscus rosasinensis	181	28	19
Gossypium sp.	131	21	17
Salanum melongena	158	19	15
Psidium guajava	123	14	13

Although there was rapid development of the nymph on *P. guajava*, it is the least preferred host for *A. gossypii* as fecundity and longevity are the lowest on this host.

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The Aphids : 403.408

A COMPARISON OF THE REPRODUCTIVE PATTERNS OF APTEROUS AND ALATE VIRGINOPARÆ OF THREE SPECIES OF APHIDS

INTRODUCTION

Aphids are the most vulnerable plant pests and they are of world wide distribution infesting almost all species of plants. In spite of the great biological and ecological importance of aphids and their easy availability as experimental material, there are relatively very few records regarding their reproductive patterns and life-histories. Moreover, those which are available only describe that of apterous virginoparae excepting a few like Markkula and Myllymaki (1963), and Patricia and Wellington (1975) who described the reproductive patterns of apterous and alate morphs of *Rhopalosiphum padi* (L.), *Macrosiphum avenae* (F.), *Acyrthosiphum dirhodum* (Wlk.) and *Acyrthosiphon pisum* (Harries).

Aphids offer numerous opportunities for comparative studies. They may have different types of morphs, and they may exhibit a variety of ecological characteristics i. e., monophagous or polyphagous, solitary or gregarious, etc.

An attempt has been made here to put data on the reproductive patterns of apterous and alate virginoparae of three species of aphids, viz., *Aphis craccivora* Koch., *Lipaphis erysimi* (Kalt.) and *Rhopalosiphum maidis* (Fitch).

MATERIALS AND METHODS

Stock cultures of *A. craccivora*, *L. erysimi* and *R. maidis* were maintained on bean, cabbage and maize leaves respectively in the laboratory at 27 ± 3°C and RH 65 ± 2 %. Newly emerged adults of apterous and alate morphs, 20 from each group were allowed to reproduce separately inside glass petri dishes on their respective host leaves. Fresh leaves were supplied every 24 hours. The duration of pre-reproductive, reproductive and post-reproductive periods were recorded. Daily records of the number of offspring produced both by apterae and alatae were taken note of. The total number of nymphs produced were counted and longevity was noted.

RESULTS AND DISCUSSION

The basic characteristics of the reproductsve behaviour of the apterae and alatae of the three species are set in Table 1.

In all the three species, it was observed that the duration of reproductive and post-reproductive period was higher in apterae than that of alatae. Apterae of all the three species had a longer life span and they were more fecund than the alatae. The maximum mean daily fecundity was also higher in the apterae. At the same time, the alatae of all the three species had a longer pre-reproductive period. The explanation for the longer pre-reproductive period lies in the migratory tendency of the winged morphs.

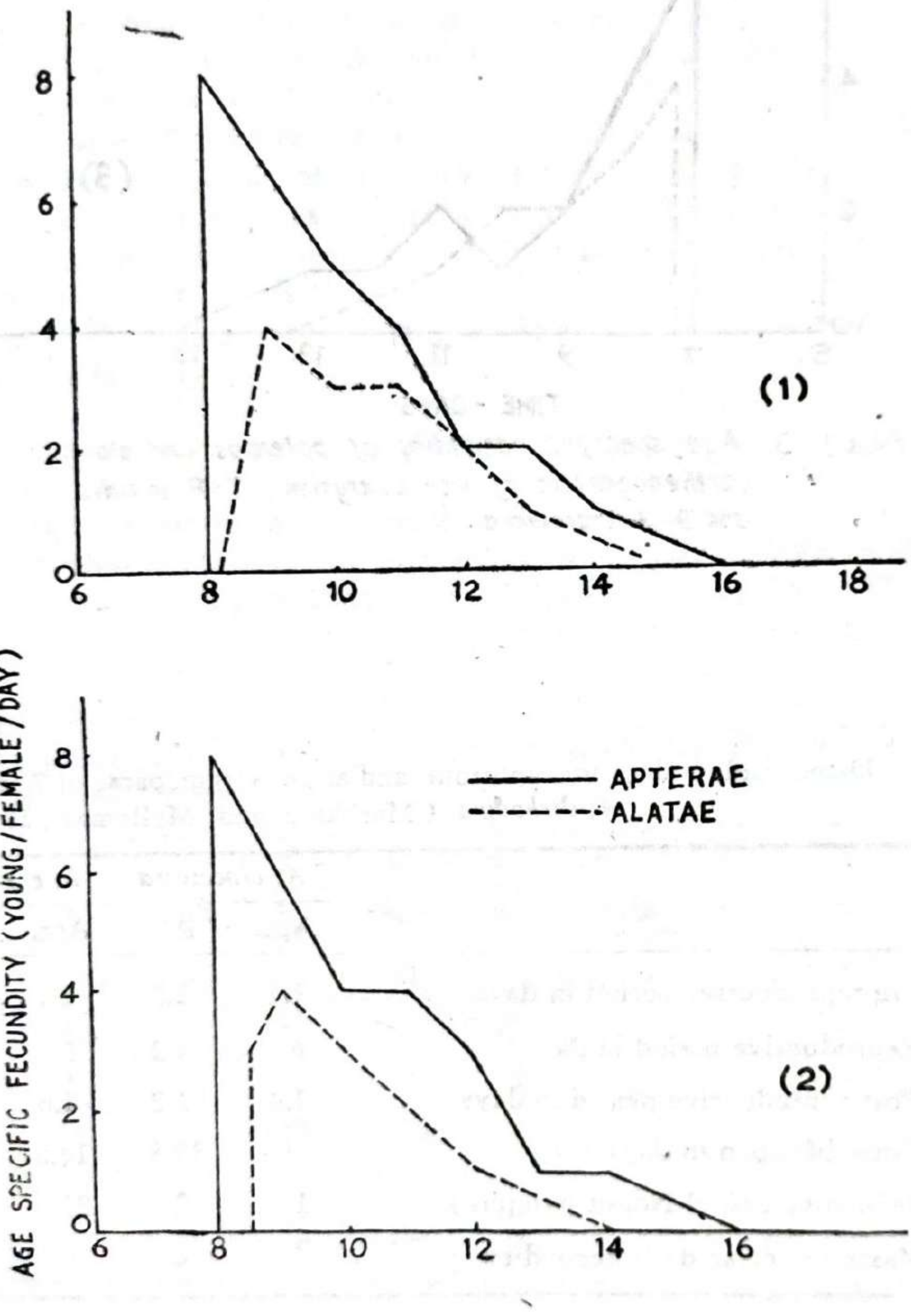
They become restless for some time instead of laying nymphs immediately and wander and fly inside the petri dishes. After some time they settle down, begin to feed and then give birth to the young. The period of this migratory habit prior to laying offspring appeared to be more in the case of *R. maidis*.

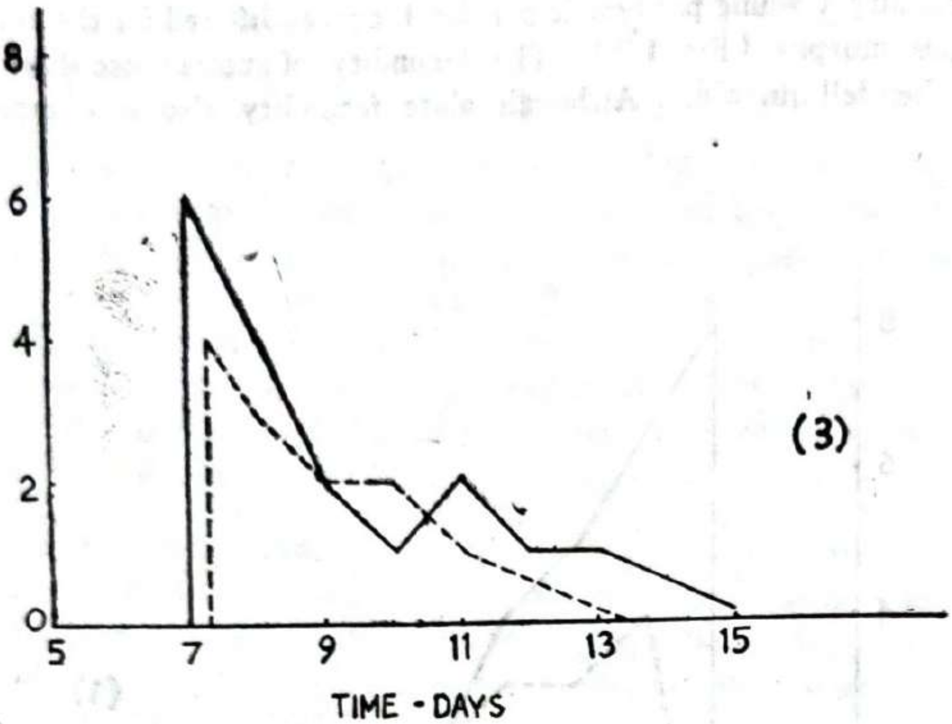
TABLE 1

Demographic data for apterous and alate virginoparae of *A. craccivora*, *L. erysimi* and *R. maidis* maintained in the laboratory on bean, cabbage and maize leaves respectively at 27 ± 3°C and RH. 65 ± 2 %.

	A. craccivora		*L. erysimi*		*R. maidis*	
	Apt.	Al.	Apt.	Al.	Apt.	Al.
1. Pre-reproductive period in days	1.1	1.3	1	1.2	1.2	1.5
2. Reproductive period in days	6	4.2	6	5.2	7.2	4
3. Post-reproductive period in days	1.4	1.2	1.6	1	1.5	1
4. Total life span in days	16	13.8	16.5	14	17	14
5. Fecundity (nymphs)	16	12	22	13	27	14
6. Maximum mean daily fecundity	6	4	8	4	8	3

When the adults began to reproduce, the shapes of the age specific fecundity (young per female per day) curves differed for the alate and apterous morphs (Fig. 1-3). The fecundity of apterae rose sharply to a peak, then fell quickly. Although alate fecundity also rose rapidly, it





Figs. 1-3. *Age specific fecundity of apterous and alate parthenogenetic of 1- L. erysimi, 2- R. maidis and 3- A. craccivora.*

TABLE

Demographic data for apterous and alate virginoparae of 7 species *A. dirhodum* (Markkula and Myllymaki, 1963)]

	A. craccivora		*L. erysimi*	
	Apt.	Al.	Apt.	Al.
1. Pre reproductive period in days	1.1	1.3	1	1.2
2. Reproductive period in days	6	4.2	6	5.2
3. Post reproductive period in days	1.4	1.2	1.6	1
4. Total life span in days	16	13.8	16.5	14
5. Fecundity (total No. of nymphs)	16	12	22	13
6. Maximum mean daily fecundity	6	4	8	4

crested at a lower level and also maintained for 4-5 days against 6-8 days for the apterae. Consequently the alatae produced significantly fewer young than the apterae (Table 1). Markkula and Myllymaki (1963) studied the reproductive patterns in alatae and apterae of three species of aphids, viz., *Rhopalosiphum padi* (L.), *Macrosiphum avenae* (F.) and *Acyrthosiphum dirhodum* (Wlk.), and Patricia and Wellington (1975) of *Acyrthosiphon pisum* (Harris). Considering all the seven species together namely, these four species and the three species studied by us, it is seen that longer pre-reproductive period in the alatae is the characteristic of all. The reproductive period varied in length. The longer reproductive period in apterous morphs in our observations agrees with that of *A. dirhodum* only. Apterae of all species have a longer post-reproductive period than the alatae, excepting in *R. padi*. The greater life span of apterous morphs in the species studied by us conforms with that of *A. dirhodum* and contradicts that in *R. padi*, *M. avenae* and *A. pisum* where alate morphs have a greater longevity. In all the seven species fecundity is higher in apterae.

Kennedy and Stroyan (1969) examined the functions of different morphs of aphids and suggested a division of labour between assimilation and growth (as measured by generation time, fecundity, etc) and sensori-motor processes (leading to dispersal or migration). This view has found support in the investigations of Patricia and Willington (1957) in

2

of aphids, namely *A. craccivora, L. erysimi, R. maidis,* [*R. padi*, *M. avenae*, and *A. pisum* (Patricia and Wellington, 1975).

R. maidis		*R. padi*		*M. avenae*		*A. dirhodum*		*A. pisum*	
Apt.	Al.	Apt.	Al,	Apt.	Al.	Apg.	Al.	Apt.	Al.
1.2	1.5	9	12	21	23	.13	15	8.2	10
7.2	4	30	31	21	29	24	20	14.8	17
1.5	1	5	6	6	5	9	8	6.2	4.3
17	14	44	49	48	57	46	43	29.3	31.4
27	14	75	37	35	26	23	15	95	86.2
8	3	—	—	—	—	—	—	10	7.6

A. pisum. The shape of the age specific fecundity curves in the three species of aphids studied by us (Fig. 1) also supports the above authors implying a considerable difference in the reproductive efforts of the aphid morphs.

The lower mean fecundity of alatae can be attributed to the increased cost of flight. The delayed onset of reproduction among alates can be attributed to the extra time required by the newly moulted adult to prepare for flight (Patricia and Wellington, 1975).

The 'r' and 'K' hypothesis given by Mac Arthur and Wilson (1967) suggests that the invaders of new habitats should have higher reproductive rates than the occupied ones and this may be applied to aphids, but it does not seem to apply to the alate morph of the species studied here because they do not have the higher reproductive rate called for by the hypothesis. Patricia and Wellington (1975) rightly suggest that further ecological and behav ioural information about different aphid species are to be gathered to shed more light on this problem.

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APHIDS OF UDAIPUR, RAJASTHAN

Raychaudhuri and Ghosh (1959, 1962) recorded eight species of aphids from Rajasthan. Joshi and Mathur (1967) supplemented the list with five more species. The southern plateau of Rajasthan, which has altogether a different topography than the rest of the state has practically remained unsurveyed. This region is situated within the parallels 23°.49' and 25°.28' N latitudes and 73°.1' and 75°.49' E longitudes. The maximum length from north to south is 20, 419.81 km. and extreme breadth from east to west is 262.26 km. The area is mostly rocky with large lakes and is densely covered with a wide variety of vegetation. This includes the regular agricultural crops and several forms of deciduous trees and shrubs. The mean altitude of this basin is 609.6 metres above sea level. The general character of the vegetation of Udaipur is trophophilous and shows occurrence of xeropgytic features. There are no herbaceous epiphytes and cryptogams are poorly represented. In general the climate and temperature varies from 2 to 38°C. The mean rain fall is 72 cm., which is precipitated mostly hetween June and September. A survey of aphids infesting principal crops of the area was therefore undertaken and in all 17 species belonging to 6 subfamilies of Aphididae inhabiting 77 host plants were collected during 1965-66. A list of such collections is presented in this paper.

TABLE 1

Aphids of Udaipur, Rajasthan together with their host plants.

Host plant	*Aphid species*
1. *Acalypha indica* Linn. (Acalypha)	*Aphis (Cerosipha) gossypii* Glover
2. *Allium cepa* Linn. (Onion)	*Tetraneura hirsuta* (Baker)
3. *A. sativum* Linn. (Garlic)	,, ,, ,,
4. *Althaea rosea* L. (Hollyhock)	*Aphis nerii* Fonscolombe *Myzus (Nectarosiphon) persicae* (Sulzer)
5. *Anona squamosa* L. (Shareefa)	*Macrosiphum euphorbiae* (Thomas)

Table 1—(Contd.)

6. *Brassica campestris* Linn. (Turnip)	*Brevicoryne brassicae* (Linnaeus) *Lipaphis erysimi* (Kalt.) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
7. *B. oleracea* var. *botrytis* Linn. (Cauliflower)	*Brevicoryne brassicae* (Linnaeus) *Lipaphis erysimi* (Kalt.) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
8. *B. oleracea* var. *capitata* Linn. (Cabbage)	*Brevicoryne brassicae* (Linnaeus) *Lipaphis erysimi* (Kalt.) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
9. *B. oleracea* var. *caulorapa* Paso. (Knolkhol)	*Brevicoryne brassicae* (Linnaeus) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
10. *Calotropis gigantea* R. Br. (Calotropis)	*Aphis nerii* Fonscolombe *Macrosiphoniella sanborni* (Gillette)
11. *Capsicum annum* L. (Chillies)	*Tetraneura hirsuta* (Baker) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
12. *C. frutescens* L. (Chillies)	*Tetraneura hisuta* (Baker) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
13. *Carica papaya* L. (Papaya)	*Toxoptera aurantii* (Fonscolombe) *Hyadaphis coriandri* (Das) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
14. *Carissa carandas* Linn. (Karonda)	*Tetraneura hirsuta* (Baker)
15. *Carthamus tinctorius* Linn. (Safflower)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
16. *Cestrum nocturnum* L. (Rat-ki-Rani)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
17. *Chrysanthemum indicum* Linn. (Chrysanthemum)	*Macrosiphoniella sanborni* (Gillette) *Macrosiphum euphorbiae* (Thomas) *Uroleucon carthami* Lambers

Table 1—(*Contd.*)

18.	*Citrus limonia* Osbeck (Lemon)	*Aphis* (*Cerosipha*) *gossypii* Glover
19.	*Citrullus vulgaris* Schrad (Watermelon)	*Aphis* (*Cerosipha*) *gossypii* Glover
20.	*Cordia myxa* Linn. (Lasora)	*Myzus* (*Nectrosiphon*) *persicae* (Sulzer)
21.	*Coriandrum sativum* Linn. (Coriander)	*Aphis nerii* Fonscolombe *Hyadaphis coriandri* (Das) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
22.	*Crotalaria juncea* Linn. (Sunhemp)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
23.	*Cucumis melo* L. (Muskmelon)	*Aphis* (*Cerosipha*) *gossypii* Glover
24.	*C. sativus* L. (Cucumber)	*Aphis* (*Cerosipha*) *gossypii* Glover
25.	*Cuminum cyminum* L. (Zeera)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
26.	*Cyamopsis tetragonoloba* (Guar)	*Rhopalosiphum rufiabdominalis* (Sasaki)
27.	*Datura fastuosa* Linn. (Datura)	*Macrosiphoniella sanborni* (Gillette)
28.	*D. metel* Linn. (Datura)	*Macrosiphoniella sanborni* (Gillette)
29.	*Daucus carota* Linn. (Carrot)	*Brevicoryne brassicae* (Linnaeus)
30.	*Dolichos lablab* Linn. (Bean)	*Aphis craccivora* Koch *Rhopalosiphum rufiabdominalis* (Sasaki)
31.	*Duranta plumieri* Jacq. (Duranta)	*Aphis* (*cerosipha*) *gossypii* Glover *A. nerii* Fonscolombe
32.	*Gossypium hirsutum* L. (Cotton)	*A.* (*Cerosipha*) *gossypii* Glover *Toxoptera aurantii* (Fonscolombe)
33.	*Helianthus annuus* L. (Sunflower)	*Uroleucon carthami* Lambers
34.	*Hibiscus esculentus* Linn. (Lady's finger)	*Aphis* (*Cerosipha*) *gossypii* Glover
35.	*Hordium vulgare* Linn. (Barley)	*Rhopalosiphum maidis* (Fitch)
36.	*Ipomoea batatas* Lamk. (Sweet potato)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
37.	*Lawsonia inermis* Linn. (Mehndi)	*Aphis* (*Cerosipha*) *gossypii* Glover *Uroleucon carthami* Lambers
38.	*Luffa acutangula* Roxb. (Ridge gourd)	*Aphis craccivora* Koch

Table 1—(*Contd.*)

39.	*Lycopersium esculentus* Mill (Tomato)	*Toxoptera aurantii* (Fonscolombe) *Tetraneura hirsuta* (Baker) *Hyadayphis coriandri* (Das) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
40.	*Mangifera indica* L. (Mango)	*Aphis* (*Cerosipha*) *gossypii* Glover
41.	*Medicago sativa* L. (Lucerne)	*Therioaphis trifolii* Mon *Acyrthosiphon pisum* (Harris) *Lachnus* sp.
42.	*Melia azadirachta* Linn. (Neem)	*Lachnus* sp.
43.	*Momordica charantia* Linn. (Bittergourd)	*Lipaphis erysimi* (Kalt.)
44.	*Moringa pterygosperma* Goerin (Sojna)	*Therioaphis trifolii* Mon.
45.	*Musa sapientum* Linn. (Banana)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
46.	*Nerium odorum* Soland (Kaner)	*Aphis craccivora* Koch *A. nerii* Fonscolombe *Macrosiphum euphorbiae* (Thomas)
47.	*Nelumbium speciosum* Wild (Lotus)	*Macrosiphum euphorbiae* (Thomas)
48.	*Nicotiana tabacum* Linn. (Tobacco)	*Uroleucon carthami* Lambers *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
49.	*Oryza sativa* L. (Paddy)	*Rhopalosiphum rufiabdominalis* (Sasaki)
50.	*Papaver somniferum* Linn. (Opium)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
51.	*Pennisetum typhoides* Stapf. (Bajra)	*Rhopalosiphum maidis* (Fitch)
52.	*Petunia* sp. (Petunia)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
53.	*Phaseolus mungo* Linn. (Green gram)	*Rhopalosiphum rufiabdominalis* (Sasaki)
54.	*Piper betel* Linn. (Betel vine)	*Hyadaphis coriandri* (Das)

Table 1—(*Contd.*)

55. *Pisum sativum* L. (Pea)	*Aphis craccivora* Koch *Rhopalosiphum rufiabdominalis* (Sasaki) *Acyrthosiphon pisum* (Harris) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
56. *Poinciana regia* Bojer (Gulmohr)	*Uroleucon carthami* Lambers
57. *Prosopis spicigera* L. (Khejra)	*Lachnus* sp.
58. *Psidium guajava* L. (Guava)	*Aphis craccivora* Koch *A.* (*Cerosipha*) *gossypii* Glover
59. *Punica granatum* L. (Pomegranate)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
60. *Raphanus sativus* Linn. (Radish)	*Brevicoryne brassicae* (Linnaeus) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
61. *Ricinus communis* Linn. (Castor)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
62. *Rosa indica* Linn. (Rose)	*Macrosiphum euphorbiae* (Thomas)
63. *Saccharum officinarum* Linn. (Sugarcane)	*Rhopalosiphum maidis* (Fitch) *Therioaphis trifolii* Mon.
64. *Sesamum indicum* D C (Sesamum)	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
65. *Soja max* L. (Soyabean)	*Aphis craccivora* Koch *Rhopalosiphum rufiabdominalis* (Sasaki)
66. *Solanum melongena* L. (Brinjal)	*Uroleucon carthami* Lambers *Tetraneura hirsuta* (Baker) *Myzus* (*Nectarosiphon*) *persicae* (Sulzer)
67. *S. tuberosum* Linn. (Potato)	*Tetraneura hirsuta* (Baker)
68. *Sorghum vulgare* Persoon (Sorghum)	*Rhopalosiphum maidis* (Fitch)
69. *Spinacia oleracea* L. (Spinach)	*Brevicoryne brassicae* (Linnaeus)
70. *Tabernaemontana coronaria* Br. (Chameli)	*Therioaphis trifolii* Mon.
71. *Trichosanthus anguina* Linn. (Snake gourd)	*Lipaphis erysimi* (Kalt.)

Table 1—(*Contd.*)

72.	*Trigonella foenumgraecum* L. (Methi)	*Aphis craccivora* Koch *Acyrthosiphon pisum* (Harris) *Brevicoryne brassicae* (Linnaeus) *Myzus (Nectarosiphon) persicae* (Sulzer)
73.	*Triticum vulgare* Villars (Wheat)	*Rhopalosiphum maidis* (Fitch) *Myzus (Nectarosipon) persicae* (Sulzer)
74.	*Vigna catjang* Walp. (Cowpea)	*Rhopalosiphum rufiabdominalis* (Sasaki)
75.	*Vitis vinifera* L. (Grapes)	*Aphis (Cerosipha) gossypii* Glover
76.	*Zea mays* Linn. (Maize)	*Rhopalosiphum maidis* (Fitch)
77.	*Zinnia elegans* Jacq. (Zinnia)	*Aphis (Cerosipha) gossypii* Glover

ACKNOWLEDGMENTS

The author is indebted to Dr. R. G. Fennah (Commonwealth Institute of Entomology, London) for help in the identification of some aphid species. Thanks are also due to Mr. S. S. Verma, Department of Horticulture, University of Udaipur for providing scientific names of several host plants.

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A NOTE ON
SOME COMMON APHIDIVOROUS INSECTS OF KERALA

INTRODUCTION

Aphids play an important role either directly or indirectly limiting the agricultural production especially of cash crops in Kerala. The most important among them is perhaps the Banana aphid ***Pentalonia nigro. nervosa*** Coq., which causes the notorious bunchy top disease in plantain and the mosaic disease in cardamom. The cashew which is an important plantation and industrial crop is subjected to a serious aphid pest, ***Toxoptera odinae***. The pea aphid, ***Aphis craccivora*** Koch., causes considerable havoc to all species of pulses especially the cow pea.

A number of predators chiefly coccinellid beetles, syrphid flies, hemerobid and chrysopid lacewings, earwigs, thrips, spiders and aphelinid parasites have been reported on aphid pests of cultivated crops. Puttarudriah and Channabasavanna (1963) gave an account of the beneficial coccinellidae of Mysore. Ray (1967) found ***Menochilus (Chilomenes) sexmaculatus*** F., ***Coccinella septempunotata*** L., and larvae of two syrphid species to be common predators of aphid pests in Ranchi. Saxena ***et al*** (1970) observed large numbers of ***C. septempunctata*** and larvae of ***Xantho. gramma (Ichiodon) scutellare*** F., preying on ***A. craccivora*** in New Delhi. ***Scymnus nubilus*** Muls., has been reported as a very important predator of ***P. nigronervosa*** in Kerala (Johnson, 1972).

The present survey on the important predators of aphids in Kerala showed that ***M. sexmaculatus*** exercises a good amount of natural control on a number of species of aphids chiefly the pea aphid ***A. craccivora*** and the cashew aphid ***T. odinae***. ***S. nubilus*** which is an important predator of ***P. nigronervosa*** is also commonly found predating upon aphids on ***Eupatorium*** and other weeds. ***Pseudaspidimerous circumflexa*** Mts. is found on pea aphid, Banana aphid and aphids on Eupatorium. ***C. septempunctata*** is common on pea aphid and aphids on vegetables, viz., ***Aphis gossypii*** and ***A. malvae***. ***Verania discolor*** F., is usually found feeding on the stamens of paddy flowers and occasionally on aphids on near-by plants. The syrphid flies ***Parargus serratus*** Fabr., and ***X. scutellaris*** are found in good numbers in colonies of ***A. craccivora*** and ***P. nigronervosa***. Other predators noted include *Thea cincta* (Coccinellidae) on *A. gossypii*, *Ascarina* sp. (Syrphidae), chrysopid and Hemerobid larvae on pea aphid and a species of thrips on *P. nigronervosa* on lemon grass.

Biology and bionomies of *M. sexmaculatus* and *C. septempunctata* have been extensitvely studied by different scientists. A note on the biology of *S. nubilus* has already been published (Johnson, 1972).

BIOLOGICAL OBSERVATIONS

Host. *P. nigronervosa*

1. *Pseudaspidimerus circumflexa* (Mots.)
   (Coccinellidae : Coleoptera)

Adult: The adult beetles are broad and oval, measuring about 2.5 mm in length and 2 mm in breadth. They are active fliers feeding voraciously on aphids. On an average the beetle feeds on 12 aphids a day.

Larva: The full grown grub is 3.6 mm long and 2.3 mm broad. It is flat, slightly convex dorsally and nearly flat ventrally, body segments flatten out sideways. Segmentation distinct. Each segment is broader than long. The grub moves actively amidst the aphid colony. When disturbed it curls up raising its anterior and posterior ends. The final instar grub eats nearly 20 aphids a day.

Pupa: The full grown grub fixes itself by its anal end to the substratum by means of excrementitious matter. It is broadly oval and strongly convex dorsally measuring about 3 mm in length and 2 mm in breadth. The pupal period lasts about 5 to 6 days.

2. *Parargus serratus* Fabr. (Syrphidae : Diptera)

Adult: The adult is a small fly, 5 mm long and 2.5 mm broad. Thorax black with a '∩' shaped white marking dorsally. Abdomen brownish with transverse white stripes.

Egg: The egg is elongate, oval, slightly broader at one end measuring 0.68 mm × 0.27 mm. It is chalk white, the outer surface being sculptured with longitudinal series of small button—like projections.

Newly hatched maggot: The newly hatched maggot is 1.12 mm long and 0.31 mm broad. It is yellowish white, elongated, more or less cylindrical, attenuated anteriorly and broader posteriorly. The body surface is covered with very minute papillae.

Full grown maggot : The full grown maggot measures a length of 8 mm and a breadth of 2.3 mm. It is highly convex dorsally and flat ventrally. Segmentation is obscure owing to the transverse corrugation of the body.

The maggots move about actively in aphid colonies. A maggot which is not starved, usually does not suck out an aphid completely. After sucking up a little juice from one aphid it discards it and goes in for another one. This habit of the maggot renders it a very potent predator. The final instar maggot feeds about 41 aphids a day.

Pupa : The puparium is greyish brown, oval anteriorly, narrow posteriorly and highly arched above. Pupa is 6.5 mm long and 2.1 mm broad. The anterior-most region of the puparium separates out like a lid to give way to the emerging fly. Pupal period is about 5 days.

3. ***Verania discolor*** F. (Coccinellidae : Coleoptera)

Adult : Body oval. Female 4.8 mm long and 3.7 mm broad. Males are slightly smaller than the females. A beetle consumes about 50 aphids a day.

Mating and oviposition : Mating takes place on the second or third day after emergence from the pupa. It lasts two to three hours. Repeated mating is also observed. The female beetle starts egg laying on the succeeding day of the first mating. Eggs are laid in groups of 8-30 among the aphid colonies. A single female is capable of laying up to 1693 eggs during its life time of 78 days.

Egg : The egg is cigar-shaped measuring 1.13 mm × 0.53 mm, deep yellow when laid and light yellow when about to hatch. Chorion is smooth and shiny. Incubation period is 2 to 3 days.

Larva:

First instar—The newly hatched grub is 1.4 mm long and 0.5 mm broad. It is light grey in the beginning, subsequently turning deep grey with head darker. The body is fusiform, sub-depressed and broadest at the metathoracic segment. Duration of first instar grub is 1 to 2 days.

Second instar—The grub is elongate and sub-depressed measuring 3 mm × 0.8 mm. Body is light grey with head and legs black. Second instar lasts 1 to 2 days.

Third instar—Newly moulted third instar grub is 4.5 mm long and 1.05 mm broad. It is black with white patches on meso- and meta-thorax and first and fourth abdominal segments. It is very active. The third instar lasts 2 days.

Fourth instar—The full-grown grub measures 8 mm × 1.5 mm. There are several setae between thoracic prominences which are comparatively smaller. Duration of the final inster larva is about 2 days.

It is seen that one grub from 1st to last instar could consume 164 to 192 aphids.

Pupa: It is oval and measures 4.6 mm × 2.6 mm. It is deep yellowish brown when first formed, later becoming paler. The pupa is highly convex above with the head, legs and wing pads hidden below. The pupal period lasts 2 to 3 days.

ACKNOWLEDGMENT

The author is grateful to Dr. M. R. G. K. Nair, Emeritus Scientist. College of Agriculture, Vellayani for valuable suggestions.

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SEASONAL INCIDENCE OF *UROLEUCON COMPOSITÆ* THEOBALD AND ITS COCCINELLID PREDATORS

INTRODUCTION

The safflower (*Carthamus tinctorius*) an important oil seed crop, yields two commercial products, viz., the saftlower oil and the safflower dye. Its seeds give 30 to 32 per cent oil, used for culinary and illuminating purposes and also for manufacture of soap. In India, it is cultivated in most of the states and the area under cultivation is about 450 thousand hectares (Anonymous, 1976).

Uroleucon compositae Theobald is a major pest of safflower and is a serious limiting factor in the profitable cultivation of the oil seed.

MATERIALS AND METHODS

For seasonal incidence studies, the populations of the aphid and its coccinellid predator on safflower were estimated at weekly intervals. Three plots of size 4 m × 3 m were chosen on the Agronomy Farm of the Rajasthan College of Agriculture, Udaipur in a randomized block design during rabi reason of 1976-77. Fifteen plants in all were taken from 3 sub-plots. Aphids were counted randomly on three leaf whorls of each plant, while the coccinellids, *Menochilus sexmaculata* F., and *Coccinella septempunctata* L., the population of the former being high, were counted on the plant as a whole (Table 1.). Observations were taken on randomly selected 8 plants in each sub-plot. Each sub-plot had six rows of plants from which 4 rows of plants were chosen for population counts of aphids. Two border rows, one on each side were eleminated for the experimental observation to avoid border effects.

RESULTS AND DISCUSSION

U. compositae began to appear on leaf whorls of safflower from 3 December, 1975 (Table 1). Very meagre population was observed building up on these whorls up to 24 December, 1975. On first January

TABLE

Seasonal incidence of ***Uroleucon compositae*** Theobald and its ***Coccinella septempunctata*** L.) on the

Period		Temperature °C			Relative humidity %
Weeks after sowing	Date	Maximum	Minimum	Mean	
4	12-11-75	30.0	8.3	19.2	52.5
5	19-11-75	25.9	7.4	16.7	50.5
6	26-11-75	24.0	3.8	13.9	55.5
7	3-12-75	26.9	4.9	15.9	57.0
8	10-12-75	27.7	4.3	16.0	59.5
9	17-12-75	25.9	5.0	15.5	57.0
10	24-12-75	27.0	5.2	16.1	64.0
11	1- 1-76	25.7	6.4	16.1	68.5
12	8- 1-76	24.6	6.1	15.3	65.5
13	15- 1-76	21.9	6.3	14.1	67.0
14	22- 1-76	25.9	5.8	15.8	65.5
15	29- 1-76	22.3	9.4	15.8	76.5
16	5- 2-76	24.9	6.7	15.8	64.5
17	12- 2-76	28.7	9.7	19.2	62.0
18	19- 2-76	26.7	8.9	17.8	65.5
19	26- 2-76	29.7	7.1	18.4	55.5
20	5- 3-76	30.7	11.3	21.0	40.5
21	12- 3-76	29.4	13.6	21.5	43.0
22	19- 3-76	30.1	13.0	21.6	52.0
23	26- 3-76	32.6	15.2	23.9	41.0

Aphids : Correlation coefficient (γ) for temperature = − 0.611
value of test for significant (t) of temperature = 5 % = 0.482,
Correlation Coefficient (γ) for humidity = + 0.7466
Values of test for significant (t) of humidity 5 % = 0.482, 1 %

1

coccinellid predators (***Menochilus sexmaculata*** **F.,**
safflower, ***Carthamus tinctorius.***

Mean Population of aphid/ leaf whorl	Mean population of coccinellids/plant				Total Coccine-llids/plant
	M. sexma-culata **F.**	***C. septem-punctata*** **L.**	***B. sutu-ralis*** **F.**	***T. 16 notata***	
0-0	0-0	0-0	0-0	0-0	0-0
0-0	0-0	0-0	0-0	0-0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.2	0.0	0.0	0.0	0.0	0.0
0.6	0.0	0.0	0.0	0.0	0,0
2.2	0.0	0.0	0.0	0.0	0.0
11.2	0.4	0.2	0.0	0.0	0.6
29.4	0.5	0.4	0.1	0.0	1.0
47.7	0.7	0.6	0.2	0.1	1.6
80.5	1.0	0.6	0.1	0.0	1.7
102.5	1.2	1.0	0.2	0.1	2.5
126.6	1.3	1.2	0.1	0.1	2.7
139.8	1.8	1.5	0.1	0.1	3.5
119.6	2.8	2.2	0.4	0.7	6.1
55.6	2.4	2.8	0.5	1.2	6.9
41.6	2.1	1.9	0.4	1.3	5.7
14.2	1.9	1.1	0.3	0.7	4.0
7.5	0.7	0.4	0.1	0.2	1.4
4.5	0.3	0.2	0.1	0.3	0.9
0.2	0.1	0.1	0.0	0.0	0.3

1 % = 0.606 Coccinellids Non-significant

0.606.

a sudden increase was recorded with rise in population to 30 per leaf whorl. This assumed still higher proportion reaching to about 80 per leaf whorl by 15 January, 1976. From January 15, up to 12 February population of aphids inereased tremendously being 102 to 140 per leaf whorl. This can certainly be assumed to be the peak period of activity for this aphid. During this period plants also developed flower buds. Sudden fall in the population to the extent of about 50 per cent was recorded on 19 February, 1976 and thereafter it declined gradually up to 26 March, 1976 when it reached to the proportion recorded on 3 December, 1975 i. e., precisely the level at the start of its appearance.

Temperature and humidity are the two main environmental factors best known to affect the population of aphid, their development and multiplication.

During December, when the mean temperature was 15.8°C and relative humidity 59.4 per cent the aphid population was at a low ebb being only 10.3 per leaf whorl. With the rise in average temperature during January and February by 1°C i. e., 17.1°C and rise in humidity by 7 to 8 per cent i. e., 66-67 per cent the population per leaf whorl increased from 65 to 110. In March when the mean temperature rose to 21.3°C and relative humidity came down to 46 per cent, the aphid population again showed a sharp fall being 13.6 per leaf whorl.

Thus, it could be concluded that with the fall in temperature and rise in humidity during January and February the population of *U. compositae* increased to a high level and with the rise in temperature and fall in relative humidity in March the population showed a sharp decline.

The data were analysed statistically calculating the coefficient of correlation between temperature and humidity prevailing during these months and population of aphids, which revealed that the rise in aphid population is negatively correlated with temperature and positively so with the humidity.

These findings are in close agreement with the findings of Trehan and Halleppanwar (1949), David (1956), Narayan (1961) and Bindra *et al.* (1964), who reported that the peak period of activity of the aphid on safflower extends from middle of January to middle of February.

The seasonal incidence of coccineilids predating on *U. compositae* was recorded. The correlation coefficient of coccinellids with the temperature and humidity was found to be non-significant. However, on the basis of data presented in table 1 it can be observed that the incidence of coccinellids started from the last week of December, 1975 and reached its peak on 15 February, 1975. Thereafter the population gradually decreased with the increase in temperature and decrease in relative humidity. The population of coccinellids was maximum when the population of aphids was at the peak.

Sethi and Atwal (1964) observed that eggs, larvae and pupae of *Coccinella septempunctata* L., developed more quickly at 35°C and 30°C than at 20°C. Gupta (1966) also found that the rise in population of *Menochilus sexmacuata* F., depended on the rise in temperature combined with the fall in humidity.

Present findings as well as those of the above mentioned workers also indicate that the coccinellid predators increase in numbers with the rise in temperature and fall in humidity.

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ESTIMATION OF LOSS DUE TO *UROLEUCON* (= *DACTYNOTUS*) *SONCHI* (LINN.) IN THE YIELD OF SAFFLOWER

INTRODUCTION

Safflower suffers from serious damage due to the aphid *Uroleucon* (= *Dactynotus*) *sonchi* (Linn.) during winter in Maharashtra. The present investigation was undertaken to assess the losses due to the aphid, *D. sonchi* in the yield of safflower (*Carthamus tinctorius*).

MATERIALS AND METHODS

Field experiments were conducted in paired plots with five replications at Agriculture College Farm, Parbhani during the winter of 1977-78 and 1978-79. The plot size was 5.4 m × 3.0 m. One set of plots was treated with 0.03 per cent dimethoate 30 EC regularly for the control of aphids at an interval of 10 days starting from 30 days after sowing at which time the aphids appeared in the field. Another set was allowed to develop natural infestation by the aphids. The observations were recorded on the population of aphids and on the yield contributing characters viz., primary branches per plant, secondary branches per plant, plant height, number of capitula per plant, capitulum diameter, seeds per capitulum, hundred seed weight, and on the yield of safflower.

RESULTS

The results obtained during the winter of 1977-78 are given in Table 1. The treated plots showed negligible infestation of the aphid species but the untreated plots were heavily infested. The incidence of other pests was negligible. The total number of capitula per plant and yield were significantly less in untreated plots than in the treated plots. The mean percentage of infested capitula per plant was 0.68 in untreated plots as against 0.0 per cent in treated plots.

The results obtained during the winter of 1978-79 are presented Table 2. The mean population of aphids per leaf in treated plots was 0.7 and 12.12 in untreated plots. It was observed that the percentage of

TABLE 1

Effect of incidence of the aphid, *Uroleucon (= Dactynotus) sonchi* on the yield of safflower (1977-78).

Particulars	Treated plots	Untreated plots	Per cent loss in untreated plots	t Test at 5%
Average number of aphids / leaf	0.0	19.3		Significant
Average number of capitula / plant	18.64	10.76	42.2	Significant
Average number of infested capitula / plant	0.0	0.68		Significant
Average yield / ha. (kg.)	617	244	60.45	Significant

TABLE 2

Effect of incidence of the aphid, *Uroleucon (= Dactynotus) sonchi* on the yield of safflower (1978-79).

Particulars	Treated plots	Untreated plots	Per cent loss in untreated plots	t Test
Average number of aphids / leaf	0.7	12.12		**
Primary branches per plant	8.2	5.8	29.26	*
Secondary branches per plant	9.80	5.46	44.28	NS
Average plant height (cm)	58.00	56.16	3.17	*
Average number of capitula / plant	19.44	12.08	32.71	*
Capitulum diameter (cm)	9.78	6.49	33.64	**
Seeds / capitulum	25.76	18.96	26.39	**
Hundred seed weight (g)	14.00	9.60	31.42	**
Seed yield/ha. (kg.)	715	325	54.54	**

* Significant at 5 % level

** Significant at 1 % level

loss in the untreated plots in the yield contributing characters viz., primary branches per plant, secondary branches per plant, plant height, number of capitula per plant, capitulum diameter, seeds per capitulum, and hundred seed weight were 29.26, 44.28, 3.17, 32.71, 33.64, 26.39 and 31.42 respectively. The percentage of loss in seed yield was 54.54. Excepting the secondary branches per plant, the yield contributing characters showed significant differences in the treated and untreated plots.

Thus it would be evident from the foregoing that due to aphid infestation on safflower 381 kg. of seed is lost which could be avoided by application of suitable insectidides.

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FIELD EVALUATION OF CERTAIN INSECTICIDES FOR THE CONTROL OF *MYZUS PERSICÆ* (SULZER) ON CHILLIES

INTRODUCTION

Chilli is an important commercial crop in Andhra Pradesh. During 1976-77 the crop was found to be severely damaged by ***Myzus persicae*** (Sulz.) in the districts of Guntur, Warangal, Karimnagar, Nizamabad, Khammam and Kurnool. *Myzus persicae* Sulz., is a serious pest of tobacco and also attacks mustard, radish, peach, potato and other solanaceous crops (Bunzil and Buttiker, 1959). Apart from *Aphis gossypii* G., ***M. persicae*** is also recorded as a pest on chilli from Poona (Deshpande, 1958). To evaluate the efficacy of different chemicals for the control of ***M. persicae*** a field trial was taken up at Warangal, Andhra Pradesh, during 1976-77.

MATERIALS AND METHODS

The trial was laid out in simple randomized block design replicating thrice with 10 treatments of 10 × 6.5 sq m each. Nine insecticides viz., phosphamidon, dimethoate, monocrotophos, methyl demeton, phosalone, quinalphos and malathion @ 0.5 kg a. i. / ha each and kerosine emulsion with fish oil rosin soap and tobacco decoction @ 2 %. The efficacy of these insecticides was assessed on the basis of percentage mortality of the insect.

Population of aphids was recorded by counting the number of aphids of different stages i. e., nymphs, adults and winged adults separately on three tagged leaves per plant in six plants per plot. The observations were recorded at pre-treatment and 2, 4 and 7 days after treatment

OBSERVATIONS AND DISCUSSION

Small, ovate, soft, greenish brown sluggish nymphs and adults of the aphid species were found in large colonies on the under surface of leaves, and growing parts including floral parts and fruits of chilli plants. The honeydew excreted by the aphids favoured the development of blackish sooty mould covering the leaves, twigs and pods. This blackish coating hinder the photosynthetic activity of the plant (Bhutani, 1976) resulting in retardation in crop growth and in severe cases drying up of the plants. This results in variable losses in yield and quality of the pods (Dominick 1949; Chamberlin, 1958).

During the survey it was found that this particular aphid was breeding on many other host plants like Bhendi, mustard, cluster bean, *Portulaca oleracea*, *P. quadrifeda* and *Chrosophora rottleni*. During the investigation it was also noticed that *Ocemum* sp. (Rudrezeda plant) was not found to have any aphid even though they were intermixed with chilli plants which were heavily infested with the pest.

As there was no significant difference in the pre-treatment counts between the different treatments, the percentages of population on 2, 4 and 7 days after treatment were recorded and are presented in table 1.

From the results (table 1) it is seen that all the insecticidal treatments were found to be significantly superior over the control in reducing the aphid population at 2 days after treatment while, methyl demeton, monocrotophos, phosphamidon and dimethoate were found to be significantly better than all other treatments. At 4 and 7 days after treatment methyl demeton and monocrotophos @ 0.5 kg a. i. / ha are only found to be significantly superior over all other treatments followed by dimethoate and phosphamidon in minimising the aphid population. The next best treatment quinalphos was found to be superior over phosalone, tobacco decoction, kerosine emulsion with fish oil rosin soap and malathion at 4 and 7 days after treatment. Though all treatments were found to be superior over the control at 2 days after treatment, tobacco decoction, kerosine emulsion with fish oil rosin soap and malathion were on par with the control at 4 and 7 days after treatment. Phosalone was found to be significantly superior over control in keeping the pest at low level at 2 and 4 days after treatment and it could not keep the pest under check beyond 7 days after the treatment.

Sarup *et al.*, (1967) reported that dimethoate and phosphamidon were found to be effective in controlling *M. persicae*. Butani (1976) reported that this pest can be controlled by phosphamidon and monocrotophos @ 0.02 % and 0.03 % respectively. In the present study methyl demeton and monocrotophos were found to be significantly sup rior in reducing aphid population followed by dimethoate and phosphamidon @ 0.5 kg a. i. / ha.

TABLE 1

Table showing the percentage of population of* Myzus persicae *at 2, 4 and 7 days after treatment in ralation to pretreatment observations.

Treatment	Dosage Kg. a.i./ ha.	Mean percentage of population present in relation to pre-treatment observation on		
		2 DAT	4 DAT	7 DAT
1. Phosphamidon	0.5	8.0 [16.2]	27.7 [32.7]	50.0 [45.2]
2. Dimethoate	0.5	9.0 [17.3]	23.0 [27.8]	43.7 [40.6]
3. Monocrotophos	0.5	7.7 [15.6]	2.7 [9.1]	12.7 [20.6]
4. Methyl demeton	0.5	5.3 [13.2]	2.0 [6.5]	10.7 [18.9]
5. Phosalone	0.5	63.0 [53.2]	78.0 [63.9]	96.3 [85.5]
6. Quinalphos	0.5	43.7 [41.4]	55.7 [48.3]	84.3 [66.9]
7. Malathion	0.5	86.3 [73.4]	100.0 [90.0]	100.0 [90.0]
8. Kerosine emulsion with fish oil rosin soap 2 %		77.3 [62.3]	90.0 [78.9]	99.3 [87.3]
9. Tobacco decoction (2 Kgs/100 litres).		64.3 [55.1]	88.7 [78.1]	100.0 [90.0]
10. Control		100.0 [90.0]	100.0 [90.0]	100.0 [90.0]
'F' test at 5% level		Significant	Significant	Significant
S. E.		7.6	6.86	5.79
C. D.		15.96	14.42	12.16

Figures in parenthesis indicate the mean of angular transformed values of percentages.

Data analysed by angular transformation.

DAT = Days after treatment.

Kareem *et al.*, (1977) reported that for the control of *M. persicae* on red pepper, monitor 0.05 %, monocrotophos 0.1 % and monocrotophos 0.05 % + DDVP 0.05 % are most effective as foliar sprays. The efficacy of monocrotophos even at 0.05 % in effectively controlling the aphid species was observed in the present investigation.

ACKNOWLEDGMENTS

The authors are thankful to Sri P. Manimantha Reddy, cultivator, Warangal district for providing necessary facilities for conducting the experiment. Thanks are also due to Sri Satyanarayana, Deputy Director of Agriculture, Warangal district for providing facilities and offering valuable suggestions to carry out the experiment.

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RELATIVE TOXICITY OF SOME CONTACT POISIONS TO THE LOTUS APHID, *RHOPALOSIPHUM NYMPHÆÆ* (Linn.)

INTRODUCTION

The lotus aphid, *Rhopalosiphum nymphaeae* (Linn.) is a semiaquatic species infesting almost all types of aquatic plants. The lotus *Nelumbium speciosum* is the most common among them. It is a native crop of India and the yield is 3600 to 4600 kg of rhizomes per hectare (Bailey, 1947). Every part of the plant, e. g., the root, rhizome, leaves, flowers, stamens and seeds is employed in the preparation of one or more drugs of Ayurvedic importance. The plant is severely attacked by the aphid pest from January to March. The present investigation reports the results of our tests with eleven pesticides against *R. nymphaeae.*

MATERIALS AND METHODS

The eleven pesticides used in the experiment, viz., pyrethrins, carbaryl, fenitrothion, dimethoate, methyl demeton, phosphamidon, aldrin, dieldrin, p,p'—DDT and nicotine sulphate were formulated in the laboratory from pure (p p'—DDT) and technical grades. All the technical grades of pesticides were made into emulsions using benzene as solvent (in case of carbaryl, acetone was used as solvent) and tritron × 100 (supplied by M/s. Amrit Lal and Co., Bombay) as emulsifier. The solvent and emulsifier in the final spray were maintained at 5.0 and 0.625 per cent respectively. The pyrethrins and nicotine sulphate were commercial, 2 per cent and 40 per cent concentrates respectively and in this case different concentrations were prepared by adding requisite quantity of distilled water. The details of insecticides used with their source of supply are given in Table 1.

Freshly emerged adult viviparae of *R. nymphaeae* were used for the tests. They were kept inside petri dishes at 25 ± 1°C for six hours for pre-conditioning. Ten aphids were placed in each petri dish and were directly sprayed under Potter's tower at 24 cm mercury pressure with 1 ml of each concentration of different insecticides. The sprayed petri dishes containing the aphids were dried for about 5 minutes under an electric fan. The treated aphids were then transferred to separate petri dishes containing fresh lotus leaves as food. They were kept at 25 ± 1°C inside an incubator.

TABLE 1

Details of insecticides

Sl. No.	Common name of pesticide	Chemical name or definitions with empirical formula	Source of supply	Form in which supplied	Other name
1.	p,p'—DDT	[1,1,1,—trichloro—2,2,—bis (p—chloro—phenyl) ethane] $C_{14} H_9 Cl_5$	Separated by crystallisation from technical DDT in the laboratory.	Crystalline p,p' isomer (100 per cent purity)	
2.	Aldrin	[1,2,3,4,10,10—hexachloro—1,4,4a,5,8,8a —hexahydro—exo—1,4—endo 5,8— dimethanonaphthalene] $C_{12} H_8 Cl_6$	M/s Shell Chemical corporation, Burmah Shell Ltd., Bombay	Technical 99.5 per cent.	
3.	Dieldrin	(1,2,3,4,10,10—hexachloro—6,7—epoxy —1,4,4a,5,6,7,8,8a—octahydri—exo—1,4 endo—5,8—dimethano—naphthalene) $C_{12} H_8 Cl_6 O$	M/s Julius Hyman & Co., U.S.A. (Through M/s Shell Chemical Corporation, Burmah Shell Ltd, Bombay).	Technical 99 per cent	
4.	Carbaryl	(1—naphthyl N—methylcarbamate)	M/s Union Carbide India Ltd., Calcutta	Technical 100 percent	Sevin
5.	Phosphamidon	(dimethyl 2—chloro—2—diethylcarbamoyl—1—methylvinyl phosphate) $C_{10} H_{19} O_5 Cl NP$	M/s Ciba of India Ltd., Bombay	Technical 100 per cent	Dimecron

Table 1—(*contd.*)

Sl. No.	Common name of pesticide	Chemical name or definitions with empirical formula	Source of supply	Form in which supplied	Other names
6.	Pyrethrins	[The insecticidal constituents of pyrethrum are called pyrethrin I ($C_{21} H_{28} O_3$), pyrethrin II ($C_{22} H_{28} O_5$) cinerin I ($C_{21} H_{28} O_3$) and cinerin II ($C_{21} H_{28} O_5$)]	M/s Bombay Chemical Private Ltd., Bombay	Pyrethrum extract 2 per cent	
7.	Nicotine sulphate	[containing 40% nicotine, 1—methyl—2—(3'—pyridyl) pyrriolidine $C_{10} H_{14} N_2$ with sufficient sulphuric acid for partial neutralisation] ($C_{10} H_{14} N_2$)$_2$ $H_2 SO_4$	M/S Imperial Chemical Industries (India) Ltd., Bombay	Nicotine sulphate 40 per cent	
8.	Methyl demeton		25EC, Bayer (India) Ltd.	Technical 8.1 per cent	Metasystox
9.	Dimethoate		40EC, Tata Fison Ltd.	Technical 0.1 per cent	Rogor
10.	Fenitrothion		50EC, Tata Fison Ltd.	Technical 0.1 per cent	Sumithion
11.	Quinalphos		25EC, Sandoz India Ltd.	Technical 0.1 per cent	Ekalux

TABLE 2

Relative toxicity of different insecticides as contact poison to the lotus aphid, *Rhopalosiphum nymphaeae*.

Sl. No.	Insecticide *	Heterogenity	Regression equation	LC_{50}	Fiducial limit	Relative toxicity
1-	Pyrethrins	x^2 = 1.048 (3)	Y = 1.2734x + 2. 4783	0.000005231	0.000002204 0.000008213	1476.347
2.	Carbaryl	x^2 = 1.297 (4)	Y = 1.0653x + 2.8463	0.000007428	0.000003213 0.000015682	1068.214
3.	Methyl demeton	x^2 = 0.526 (3)	Y = 0.8231x + 3.0715	0.00001564	0.00001368 0.00001653	626.172
4.	Fenitrothion	x^2 = 1.516 (4)	Y = 1.2253x + 1.5031	0.00005631	0.00002317 0.00008175	166.456
5.	Quinalphos	x^2 = 1.712 (3)	Y = 1.8132x − 0.1073	0.00007671	0.00005213 0.00006102	164.903
6.	Phosphamidon	x^2 = 4.008 (5)	Y = 0.9102x + 2.2198	0.0001012	0.00006214 0.0002003	98.412
7.	Dimethoate	x^2 = 0.253 (5)	Y = 1.9253x − 1.3011	0.0001726	0.0001234 0.0002013	53.413
8.	Dieldrin	x^2 = 3.454 (4)	Y = 0.4623x + 2.6045	0.0001844	0.00006838 0.0003860	45.387

Table 2—(*contd.*)

Sl. No.	Insecticide	* Heterogenity	Regression equation	LC_{50}	Fiducial limit	Relative toxicity
9.	Aldrin	$x^2_{(3)} = 2.045$	$Y = 1.1628x + 0.6585$	0.0003187	0.0001432 0.0005245	20.828
10.	p,p' DDT	$x^2_{(3)} = 2.234$	$Y = 1.3690x - 0.6786$	0.009881	0.009837 0.009924	1.000
11.	Nicotine suiphate	$x^2_{(3)} = 0.348$	$Y = 0.8184x + 0.0456$	0.02218	0.01213 0.03837	0.382

* In none of these cases the data were found to be significantly heterogenous at $P = 0.05$, Y = probit kill, x = log (concentration 10), LC_{50} = concentration calculated to give 50 per cent mortality.

For the assessment of toxic effect, mortality count was taken 24 hours after the treatment. The moribund aphids were counted as dead. Each experiment with a control was replicated thrice. The mortality in the control ranged from 0 to 7% there being no significant mortility. The mortality data thus obtained were subjected to probit analysis (Finney, 1952) and are presented in Table 2. The values of relative toxicity of diffetent pesticides were calculated by taking the LC_{50} value of p,p'—DDT as unity.

RESULTS AND DISCUSSION

It is evident from Table 2 that on the basis of LC_{50} values the order of toxicity of different pesticides is pyrethrins > carbaryl > methyl demeton > fenitrothion > quinalphos > phosphamidon > dimethoate > dieldrin > aldrin > p,p'—DDT > nicotine sulphate. Out of the 11 pesticides the first 9 pesticides were more toxic than p,p'—DDT i. e., about 1476.347, 1068.214, 626.172, 166.456, 164.903, 98.412, 53.413, 45.387 and 20.828 times as toxic as p,p'—DDT. Nicotine sulphate was found to be less toxic than p,p'—DDT i. e., about 0.382 times as toxic as p,p'—DDT. It is interesting to note that pesticides of plant origin viz., pyrethrins and carbamate (carbaryl) were highly toxic to *R. nymphaeae* when compared with their toxicities to terrestrial aphid species (Sarup *et al*, 1967, 1971). With regard to the chlorinated hydrocarbons, viz., p,p'—DDT, aldrin and dieldrin, the LC_{50} values were higher for the terrestrial aphid species but proved to be effective aphicides against *R. nymphaeae*.

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ON THE INFESTATION OF *APHIS GOSSYPII* GLOV., ON COTTON (*GOSSYPIUM HERBACEUM*)

Common varieties of Cotton grown in Orissa are Sujata, Hybrid 4, MCU-5, Krishna, P. R. S. 72 and Bhara lakshmi (Mohapatra & Kar, 1976). *Aphis gossypii* is one of the major pests decreasing the yield of fibre. The present investigation deals with variation in aphid population on cotton variety MCU-5 between November, 1978 and October, 1979 at Bhubaneswar.

The field trial was conducted in the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar in a field divided into 12 subplots (area : 3m × 3m each) in North-South direction. After proper field preparation cotton seeds were sown in the first week of October, 1978 in all the subplots in three replications allowing suitable plant spacing. Watering was regularly done. When the plants reached 2-3 leaf stage, weekly observations of aphid population were recorded on dates of a month like 7, 14, 21 and 28. As such a total of 48 weekly observations were recorded for one year i. e., from 7-11-1978 to 28-10-1979. Aphid population count for all forms such as, adult alatae and apterae, and nymphs was done separately on each occasion of observation as per methods adopted by Broadbent (1948) and Khan (1976). On each date of observation 5 plants were selected at random from each subplot (having a total of 25 plants) and as such 15 plants were examined from 3 replications. From each plant 3 leaves (i. e., one from top whorl, one from middle whorl and one from bottom whorl) were selected and aphid numbers counted. Population count of aphids was never made twice on any cotton plant. On each occasion a separate plant was chosen for the purpose. Mean aphid numbers were calculated on the basis of per single leaf area. Basing on four weeks' observations mean aphid population of the month was calculated. Likewise mean meteorological factors of a month were taken into account (Table 1).

The mean number of aphids of all forms on a leaf for different months of the year were : November, 1978 (26.53), December (35.01), January, 1979 (44.02), February (30.05), March (2.05), April May and

TABLE 1

Population studies of *Aphis gossypii* on Cotton (*Gossypium herbaceum* variety MCU-5) and corresponding meteorological condition at Bhubaneswar during November, 1978 to October, 1979.

Month	*Mean number of aphids/leaf including all forms.	Meteorological factors					
		Mean Temp. (°C)	Rain fall (mm.)	Number of rainy days.	R. H. (%)	Wind velocity (Km / hr.)	Sunshine (hrs.)
November, 1978	26.53	25.9	3.4	3	71	3.4	8.9
December, 1978	35.01	21.4	24.9	2	64	4.9	9.0
January, 1979	44.02	23.0	0	0	67	4.1	9.2
February, 1979	30.50	24.5	40.8	5	64	6.4	9.7
March, 1979	2.50	28.3	1.3	1	60	8.9	9.7
April, 1979	0	31.2	85.0	3	65	12.3	9.6
May, 1979	0	32.7	34.1	5	64	12.7	10.0
June, 1979	0	32.4	110.2	20	69	12.9	7.0
July, 1979	5.33	29.6	237.7	18	80	8.8	6.4
August, 1979	7.00	29.3	368.8	16	79	7.2	5.9
September, 1979	8.33	28.7	229.8	16	83	5.0	6.5
October, 1979	9.00	28.3	94.2	11	77	3.7	9.6

* Mean number of aphids (alate, apterae and nymphs) of 3 leaves, 5 plants in 3 replications.

June (0), July (5.33), August (7.00), September (8.33) and October, (9.00). During the period of peak infestation i. e., January, the meteorological factors were : mean temperature 23.0 °C rainfall nil, R. H. 67%, wind velocity 4.1 km/hr and sunshine 9.2 hrs. Thus, for winter cropping of cotton control measures against *A. gossypii* should be taken from November to January.

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