

HOST AS AN ENVIRONMENT

Zoological Survey of India

HOST AS AN ENVIRONMENT

PROCEEDINGS OF THE SYMPOSIUM ON
HOST AS AN ENVIRONMENT FROM
27TH MARCH TO 28TH MARCH 1930,



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EDITOR'S PREFACE

Host-environment, it is widely recognised, can predictably control biology, behaviour and phenology of the organisms depending on hosts—either as obligatory or facultative parasites or as symbionts. This area of investigation has attracted attention of a number of researchers in India in recent years and Zoological Survey of India organised a symposium in 1979 to offer a common forum for discussions and consider the results so far achieved by scientists of different academic and research institutes of the country. In this symposium, a total of 19 papers were presented by 24 authors, covering such diverse area such as host environment of flagellates, haematozoans of vertebrates, parasitic helminthes and snails, relation between bat and batfly, host relation of phytophagous insects like lygaeid bugs, coccids, aphids, ecological succession of insect borers in felled trees and symbiotic association of marine animals etc ; Ecological, biochemical, behavioural, and biological aspects of the common topic of “Host as an Environment” clearly reveal the tremendous potentiality of further research to understand more precisely the intricate mechanism of host-parasite interaction.

I hope, this volume will not only be helpful to the scientists actually engaged in this area of research, but will also be providing stimulating ideas to the biologists in large.

June 15, 1983

B. K. TIKADER
Director,
Zoological Survey of India

ZOOLOGICAL SURVEY OF INDIA

PROCEEDINGS OF THE SYMPOSIUM ON HOST AS AN ENVIRONMENT

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HOST AS AN ENVIRONMEMT

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AIHHPH, Calcutta

For a life scientist, there is no other more fascinating wonderland to stroll and admire than that of the subject of host as an environment. Life has no existence without an environment, while the non-free living forms of life demand for their survival the more specific and exact environmental situations that can be assured and provided only by other animals or plants. The interactions and inter-relationships that take place as a consequence of such special encounters between the two organisms, present an amazing and staggering panorama of the wonders of the nature.

The scope of this theme is unlimited. In this paper attention is focused on the man as a provider of an environment for the parasites to live and propagate. Life has existed on the earth for millions of years, but *Homo sapiens* as a species is relatively young. It is yet to mature and to get stabilized ecologically. Naturally, there are only a small number of forms of life that have chosen man as their habitat, and many of the host-parasite relationships are still in a process of evolution and adjustment. In the process of adaptation, these parasitic forms of life have found human environment to be ranging from extremely hostile and disastrous to extraordinarily patronising and rewarding. As an inevitable outcome, the wide spectrum of reactions and relationships which develop between the parasite and its host environment, have provided to the life scientists a panorama of natural histories, the lucid examples of vagaries and fantasies that are realised by nature. The grand show does not end here. Man is an extraordinary animal. His unbounded intelligence, imagination and quest have led to his indulgence in the conquest of nature. His life style can no longer be considered as natural. Step by step, the man has advanced to influence and modify his external and internal environments so that he is able to overcome deliberately his troublesome parasites and guests. Man has to his credit the success, though solitary, in exterminating the virus of smallpox from this planet. The virus was not wise in choosing man as its obligate host, but the man is equally obstinate in continuing to provide for the smallpox virus suitable environment for survival and preservation in the

laboratories. But the nature continues its perpetual march and retrieves. The characteristic plasticity of life inherited through the in-built genetic structure, together with the vagaries of human behaviour, makes the history not only dramatic, but also more intricate and further, confusing.

For survival of the species, the human parasites have to gain entry into the body of man through the portal in one form or another. Further, it has to thrive and to multiply or transform or both, and to leave human body through proper exit. Transit from one host to the other is always hazardous for the parasite because of exposure to the unfavourable environment. Therefore, for such a passage it has to equip itself suitably for adequate safety, and also to multiply sufficiently to tide over the probable mortality. The parasite has to reach and enter a new susceptible host in time so that the life cycle continues.

Entry into the Environment :

The surface of the skin furnishes all that is necessary for the organisms such as fungi, or saprophytic organisms. However, the scabies mite is not satisfied to remain on the skin, but it burrows tunnels inside and completes its life-cycle. The septic group of organisms such as streptococci or staphylococci get entry into the body through the breaks in the skin or mucous membrane, and produce septic lesions with or without pus formation. The virus of measles enters man through the conjunctival sac of the eyes. On the other hand, many parasites such as diphtheria and tubercle bacilli use the respiratory passage and come in through the nose and throat. The easiest way is naturally through the mouth, and the organisms such as poliovirus, cholera vibrio, *Entamoeba histolytica*, the intestinal helminths, guinea worm, etc., use it freely. The gonococcus prefers the mucous membrane of the genital tract, and the larva of hook-worm and *leptospira icterohaemorrhagica* believe in self-reliance and actively pierce through the skin. The malarial parasite, the encephalitis virus, etc., employ more sophisticated method and manage to get injected into man by utilizing a vital need of the female mosquitoes for a blood meal. These and similar examples clearly show that the nature has exploited fully all the possible ways of getting the parasites into the human host.

Host Environment :

The parasitic organisms cannot be complacent even after successfully reaching man and gaining entry in him. Human desire to keep himself

clean and his habit of taking bath using soap and hot water, have disastrous impact on the surface and near surface dwellers such as lice, scabies mite and staphylococci. The parasite has to struggle against many odds. There are many types of phagocytes which actively attack and destroy the invaders. These cells are present not only in every tissue, but are transported and carried in large numbers also to the troubled spot in the body through the blood vessels. Some of the cells are specifically effective in combating some parasites selectively. The parasitic organisms have to face chemical and immunological warfare also. The weapons are both general type and made-to-order. The biochemical substances including antibodies are produced within the body, but the man has substantially added to his arsenal by inventing modern drugs, immunologicals and chemotherapy. But there is counter-action and there is evidence that the tubercle bacilli, malarial parasites, and many vectors have already blunted these defences. It seems that the plasticity of the in-built genetic structure of the various forms of life which have lived much longer than man, can undermine, weaken and even overcome the intellectual superpower of man.

Rejection :

Most of the parasitic forms of life do not prefer man as their host because of the refractory environment he provides. If such organisms encounter the human beings, these either fail to gain entry or die soon after. Most of the micro-organisms fall in this category. Most of the animal parasites do not thrive on man.

Natural Accidents :

Some non-human parasites encounter man accidentally and not by choice. But these find human host environment not very hostile. Thus, the spores of *Clostridium tetani* that contaminate the wound, germinate in the favourable circumstances and produce exo-toxins. Whether man survives or dies, both the events are immaterial for the organism which is permanently trapped in the human tissues and has to undergo life imprisonment.

A similar fate is also reached by the virus of rabies, but more tragically. This virus employs a clever approach for its transmission from host to host. It manages to change the behaviour of the infected host and makes it to attack and bite other animals. The virus multiplies in the salivary glands and gets excreted into the saliva of the host, and thus successfully transfers itself into the bite wound. But

when a rabid dog bites a man, in over 80 per cent of times, he escapes infection as the virus of rabies is rejected in toto by human tissues. In the rest of the cases the infection may set in. But the virus is unable to induce man to bite others, and just creates in him great fear for water. The disease produced in man is called hydrophobia and carries 100 per cent mortality. As a result, the virus also dies tragically with the man.

An unknown host-environment often makes the parasite to lose its way. If a filarial larva from a bird, gets accidentally injected through mosquito bite into man's skin, it fails to get into the lymphatic system and gets lost. This leads to queer forms of parasitism, one such example being transient conjunctivitis. The organism dies in the process.

Promotion :

The longer is the association between man and the parasite, more hospitable and patronising is the environment, and less damaging are the interactions. Because of long association and stabilisation of the ecological balance, most of the intestinal micro-organisms live in full symbiosis with man. The leprosy bacilli and the mumps virus have a moderately long co-existence. These infections lead to a minimal and milder reactions, if any. The mumps virus remain restricted to the salivary glands and do not damage the glands. Only occasionally, it grows in testes, ovaries and pancreas. The virus of measles or encephalitis has a short association, and these infections tend to produce violent reactions. The measles virus multiplies in many tissues and causes damage. The *Esch. coli* is generally peaceful in the intestines, except occasionally in the infants. But it misbehaves and creates problems when it enters the genitourinary tract or the peritonium.

The micro-climates are the special features of human environment. Specific tissue requirements are so vital and compulsive to some parasites that these are named after their place of residence, e. g., encephalitis virus, hepatitis virus, intestinal helminths, etc. The typhoid bacilli multiply at the patches of the lymphoid tissue of the small intestines, some of the tape worms encyst in the muscles, and the polio virus settles into the anterior horn cells of the spinal cord.

The most complex is the life of the malarial parasite. The plasmodium exists in many forms. The sporozoites from salivary glands of the vector mosquito are injected directly into the blood stream.

The liver provides the first camping ground. The exo-erythrocytic forms multiply in the liver and are released in blood periodically. The schizont nests and grows undisturbed within the red blood cells. In these cells, the parasite moves all over the body, but well protected as the astronaut is in a space ship. In the red blood cells, the male and female gametocytes also develop and wait anxiously to be picked-up by the vector mosquito. But that is not all. In the mosquito the plasmodium has to undergo a sexual cycle and multiply before the human environment can be enjoyed. Curiously, the filarial worm has chosen a reverse style. It finds man as a suitable environment for its sexual multiplication and prefers to undergo only a structural change in the mosquito, but without any multiplication.

The less thoughtful organisms such as the smallpox virus have committed genocide by choosing man as their exclusive home. On the other hand, there are wise parasites who have guaranteed their superiority by retaining the trump card with them. The greatest challenge to human intelligence seems to have been provided by the *Treponema pallidum*, the germ of syphilis, by fully exploiting the sexual behaviour of man for continuation of species. For self-propagation, the organism has made human tissues its haven, and all attempts of man to dislodge it have failed. Advances in chemotherapy have succeeded in generating only short-lived hopes for the control. Not only all the conventional preventive measures have failed, but the industrial and economic growth, and the resultant socio-cultural changes in the industrialised society, have benefited also the *Treponema*, perhaps more than the man himself.

Taenia solium needs two hosts, man and pig alternately. Adult worm is in the man and only one worm can develop in the intestines and no more. When the human faeces containing eggs is swallowed by the pig, *cysticercus cellulosae*, a cystic form, is produced in the muscles. When infected pork is eaten by the man, the adult worm develops and the cycle repeats. But when man accidentally swallows the eggs, *cysticercus cellulosae* are produced in the human muscles and the worm digs its own grave. *Hymenolepis nana* is a tape worm of the rodents, but even if man ingests the eggs, the human environment provides necessary climate for the development of the adult worm.

Some parasites truly enjoy the host environment and are acrobatic. The best example is that of the round worms. The *Ascaris lumbricoides* enters the body when man ingests the infective eggs. The larvae

emerge in the stomach and penetrate the mucosa of the intestinal tract, and enter the blood stream. They reach the lung and push their way into the bronchial tree. The larvae which have also changed their clothes a few times by now, climb up the trachea and the larynx. Summersault into the oesophagus provides the climax. The adult worms develop in the intestines where they mate and the eggs are discharged in the faecal matter.

There is no end to such interesting illustrations, but so also to man's enormous support that he continues to provide to his fellow animals through his way of life and behaviour. Modern modes of rapid travel, e. g., aircrafts, have become boon to everyone, man, his parasites, and vectors. Man is even willing to go out of way to create environments suitable for the parasites. The house-flies are his creations and he has provided newer avenues like venereal transmission of intestinal parasites and faecal organisms by engaging himself in homosexual and oral-perineal contacts with multiple partners.

Nature's activities are unabated, and even the silence may not indicate absence of activity. It is known that minute forms of life may remain totally dormant in human tissues throughout the life, e. g., the virus of chickenpox or Australia antigen. The tetanus bacilli may get transformed into spores only to await favourable climate for germination, e. g., second surgical operation.

I quote, "Man has existed on this terrestrial globe for about a million years, and astronomers tell us that in all likelihood the earth will remain habitable for very many millions of years more, provided that the ingenuity of Man and his scientific achievements do not so far out-pace his ethics as to impel him to destroy it in his urge to kill his fellow-creatures."

In conclusion, it may be said that the man has to learn to live and let live.

THE BEHAVIOUR OF *TRYPANOSOMA EVANSI* IN SOME DOMESTIC ANIMALS FROM ANDHRA PRADESH

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INTRODUCTION

'Surra' is one of the most important and wide spread diseases in domestic animals like cattle, buffaloe, horse, camel and some carnivores. It has an extremely wide geographical range in countries with hot and warm-temperate climate. The causative agent of the disease is *Trypanosoma evansi*. It was the first pathonogenic trypanosome discovered by Grefith Evans in 1880 in the blood of a dog and a camel from Punjab. Since then considerable number of reports are available on the outbreak of 'Surra' from different parts of the globe as well as from India (Hoare, 1972). In a recent survey in bovines from Krishna district, Andhra Pradesh, the disease has been reported by the present authors (Mandal *et al.* 1977). The present investigation is an attempt to understand the behaviour of *Trypanosoma evansi* in some domestic animals from India.

MATERIAL AND METHODS

Blood smears of domestic animals from Andhra Pradesh were collected by one of us (A. K. M.), stained with Leishman's or Giemsa's stain and examined for trypanosomiasis. The smears were first scanned under low power of a microscope (400x) and subsequently the level of parasitaemia was determined counting trypanosomes per 10,000 erythrocytes. The clinical symptoms were also noted from different host for effective correlation with degree of parasitosis in these animals.

OBSERVATION

Blood smears of domestic animals examined for trypanosomiasis were analyzed with respects to the percentage of occurrence in different hosts (Table 1), intensity of infection or the level of parasitaemia (Table 2) and clinical symptoms (Table 3).

TABLE 1. Occurrence of 'Surra' in different hosts from Andhra Pradesh.

Hosts	Examined	Infected	Percentage of infection
Cattle	200	22	11%
Buffalo	250	72	28.8%
Dog	20	3	15%
Sheep	40	0	—
Goat	105	0	—

TABLE 2. Intensity of infection in different hosts, parasite per 10,000 erythrocytes

Number of tryps. per 10,000 erythrocytes	Cattle	Buffalo	Dog
1. One or less	9	18	—
2. Above one and upto ten	10	42	—
3. Above ten to 100 tryps.	3	4	—
4. Above 100 to 1,000 tryps.	—	5	—
5. Above 1,000 to 10,000 tryps.	—	2	1
6. More than 10,000 tryps.	—	1	2
Total=22		72	3

TABLE 3. Clinical manifestation of Surra in different hosts.

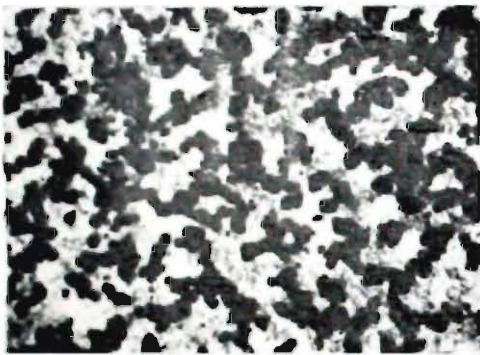
Symptomes	Cattle	Buffalo	Dog
Total positive cases	22	72	3
With temperature	4	48	3
With inflamed eye	1	5	—
With swollen legs	2	4	—
Drowsiness	20	50	—
Shaking of head/body	2	4	—
Pyrexia	5	10	—
Diarrhoea	10	20	—
Change in colour	—	5	—
Without temperature	18	24	—
Mortality	—	—	1

Out of 200 cattle, 250 buffaloes and 10 dogs ; 22 cattle, 72 buffaloes, 3 dogs were found to be infected with *T. evansi*. The sheep and goats were devoid of any trypanosomal infection. The percentage of infection is higher in buffalo (28.8%) than the others (Table 1).

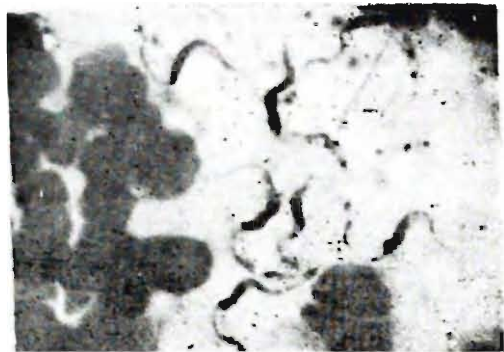
Intensity of infection was always high in dogs, less in cattle and moderate in buffaloes. The same is true for clinical symptoms and severity of parasitoses (Table 2 and 3). However, though buffaloes

MANDAL & NANDI

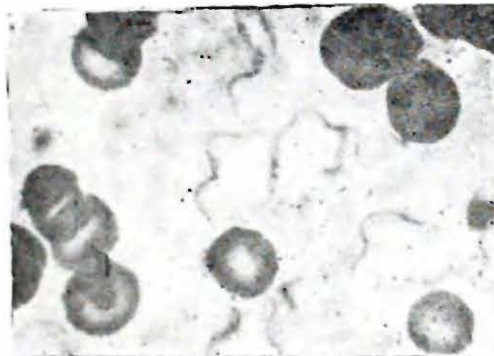
PLATE I



1



2



3

- Fig. 1. *T. evansi* infection in dog
Fig. 2. *T. evansi* infection in Buffalo
Fig. 3. *T. evansi* infection in Cow

are more prone to infection with the causative agent of surra, the degree of severity and the level of parasitaemia may vary with individuals.

DISCUSSION

The principal host of *T evansi* is the camel but horses, dogs, elephant, cattle, buffaloes and pigs are also proved to be highly susceptible (Hoare, 1972). It occurs in rats and mice. The absence of infection in sheep and goats as is also evidenced from the present investigation though living so closely in the enzootic areas is interesting. Mainly two factors can be taken into consideration for this phenomenon—one (1) The vector and the other is the antigenic reaction of the host. The most important fly vector of *T evansi* is the horse flies in the field and *Stomoxys* in the stable (Woo, 1977). They are considered as the chief agents for transmission and taking blood meal by both the vectors from these animals facilitate the transmission of infection. Still the non-infective condition in sheep & goat may be due to some antigenic reactions within the body. Moreover, as some physiological activities can also be attributed to the fact of immunizing the sheep and goats from infection of *T evansi*.

SUMMARY

Out of 200 cattle, 250 buffaloes and 20 dogs examined from Andhra Pradesh 22 cattle 72 buffaloes and 3 dogs were found to be infected with *T evansi*. The percentage of infection is higher in buffalo about 28% than the others. Whereas the intensity of infection was higher in dogs less in cattle and moderate in buffalo. The sheep and goats were devoid of any infection.

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AMINO-ACID CONSTITUENTS OF THE PLANT-SAP OF
SOME COMMON, OCCASIONAL AND NON-HOSTS OF
THE INDIAN LAC INSECT *KERRIA LACCA* (KERR)
(TACHARDIIDAE : HOMOPTERA)

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INTRODUCTION

Lac insects, like other plant-sap sucking insects, are totally dependant for their nutritional requirements on the phloem-sap of their host plants. This sap is reportedly very rich in free amino acids and carbohydrates. However, some of the constituents have been noted, in cases of other coccids and aphids, to affect susceptibility of the plant to the feeding insect. For example, in the case of groundnut aphid or cowpea aphid, *Aphis craccivora* Koch, it has been reported that when fed on different host plants, the fecundity rate was more in case of host plants having less amino acids in its sap, and the fecundity rate was lower in case of host plants having more amino acids present (Waghray & Singh, 1965).

Earlier it has been shown that the varieties of the pea plants, which are resistant to the pea aphid *Acyrtosiphon pisum* (Harris), contained comparatively lower number of free amino acids than those in the susceptible varieties of pea plants, whether the plants were grown in green house or in fields (Auclair & Maltais, 1950 ; Auclair *et al.*, 1957). Similarly susceptible alfalfa plants grown in the green house contained higher number of amino acids than the resistant ones, but interestingly such differences were reversed when plants were grown in fields (Marble *et al.*, 1959). In yet another case, Mittler (1958) has shown that the size of the aphid *Tuberolachnus salignus* (Gmelin) depends upon the nitrogen concentration of the sap of the host plant and the volume of this sap ingested. Thus, a study of the relative number of amino compounds in the sap of the host plant provides useful information on the effect of the same on the sucking insect.

The Indian lac insect, *Kerria lacca* (Kerr), feeds on a variety of plants belonging to different genera and species (Roonwal *et al.*, 1958 ;

Varshney & Teotia, 1967). The performance of the lac insect survival is obviously varied on these hosts. Accordingly, these host plants can be classified broadly into 3 categories :

(i) *Common host plants* : the plants on which the lac insect thrives very well for generation after generation ; the quantity of lac secretion on these plants is abundant ; and their performance as a lac-host is good throughout the region.

(ii) *Occasional host plants* : the plants on which the lac insect can survive for a few generations only ; or which are good as a lac-host in certain States/localities only ; thus, their performance is variable in different parts of the land.

(iii) *Non-host plants* : the plants on which the lac insect may settle, but either does not thrive, or lives for a short period only. On such plants the insects do not reach to maturity.

Among these categories, the first one may be depicted as susceptible to the lac insect, the middle as the intermediates, and the last category as resistant to the lac insect. Such a differentiation, however, is quite arbitrary, since the behaviour of the plants as a lac-host sometimes differs from locality to locality, etc.

On account of the commercial value of the lac (a resin secreted by the lac insect on host plants), the susceptible varieties of plants are more sought after rather than the resistant ones. The present study was undertaken in order to explore if there is any correlation between the free amino acids (including amides) composition of the host plant-sap and the survival of the lac insect, and whether any of the free amino acid acts as a factor in the nature of resistance of plant to the lac insect.

MATERIALS AND METHODS

Twenty plant species were selected for experiments in this study. These belong to the three categories mentioned above and are classified as follows :

Common Lac-hosts :

1. *Butea monosperma* (Lam.) Taub. (Leguminosae)
2. *Schleichera oleosa* (Lour.) Oken (Sapindaceae)
3. *Ziziphus mauritiana* Lamk. (Rhamnaceae)

Occasional Lac-hosts :

1. *Albizzia lucida* (Roxb.) Benth. (Leguminosae)
2. *Cajanus cajan* (Linn.) Druce (Leguminosae)
3. *Mangifera indica* Linn. (Anacardiaceae)
4. *Samanea saman* (Jacq.) Merr. (Leguminosae)
5. *Shorea roxburghii* G. Don. (Syn. *Shorea talura* Roxb.) (Dipterocarpaceae)

Non Lac-hosts :

1. *Anthocephalus cadamba* Miq. (Rubiaceae)
2. *Cedrela toona* Roxb. (Meliaceae)
3. *Dodonaea viscosa* Linn. (Sapindaceae)
4. *Duranta repens* Linn. (Verbenaceae)
5. *Erythropsis colorata* (Roxb.) Burkill (Syn. *Firmiana colorata* R. Br.) (Sterculiaceae)
6. *Lagerstroemia thorelli* Gagnep [? *parviflora* Roxb.] (Lythraceae)
7. *Lantana camara* Linn. (Verbenaceae)
8. *Moringa oleifera* Lam. (Moringaceae)
9. *Salix tetrasperma* Roxb. (Salicaceae)
10. *Swietenia macrophylla* King (Meliaceae)
11. *Syzygium cuminii* (Linn.) Skeels (Myrtaceae)
12. *Tephrosia candida* DC. (Leguminosae)

The plants selected for their sap extraction were of different age. However, in the case of common and occasional lac-host plants, those plants only were selected which had earlier harboured some generations of the lac insect, or were already infested.

The sap was collected from the green succulent twigs only. It was done in most cases during June-July months, when the plants were in an active period of growth. All plants used in this study are located in the campus and plantation of the Indian Lac Research Institute, at Namkum.

The sap was collected from thin shoots of plants, which were cut with a sharp razor and the exudate sap was immediately sucked in fine pipette and further carried to the laboratory for processing. Wherever the exudate could not come out of its own accord, or was in meagre volume, the cut shoot was slightly pressed with pliers and the oozing exudate drawn. Following the method of Kennedy & Mittler (1953), attempts were also made to collect the sap of the plants (phloem sap), by feeding some aphids, or the lac insect, and then severing their rostralis (stylets) by micro-scissors, but these were not successful.

The collected plant-sap exudate was individually made ready for the paper partition chromatography. All samples of sap were first centrifuged and the precipitate, if any, was discarded. The supernatant was mixed with equal quantity of ethanol and again centrifuged, and the precipitate, if any, was again discarded. The clear supernatant was kept in a micro-crucible and concentrated on a water-bath for 2 to 5 minutes.

Known quantities (5μ to 25μ) of the ethanol treated and concentrated plant sap were spotted on the chromatographic filter papers (Whatman No. 1) for two dimensional chromatography. The chromatograms were first developed in phenol-water (80 : 20 v/v), in which a few drops of NH_4OH were added to neutralize the acid content. After properly drying the chromatograms, the second development was done, at the right angle of first run, in *n*-butanol-acetic acid-water (30 : 6 : 14 v/v).

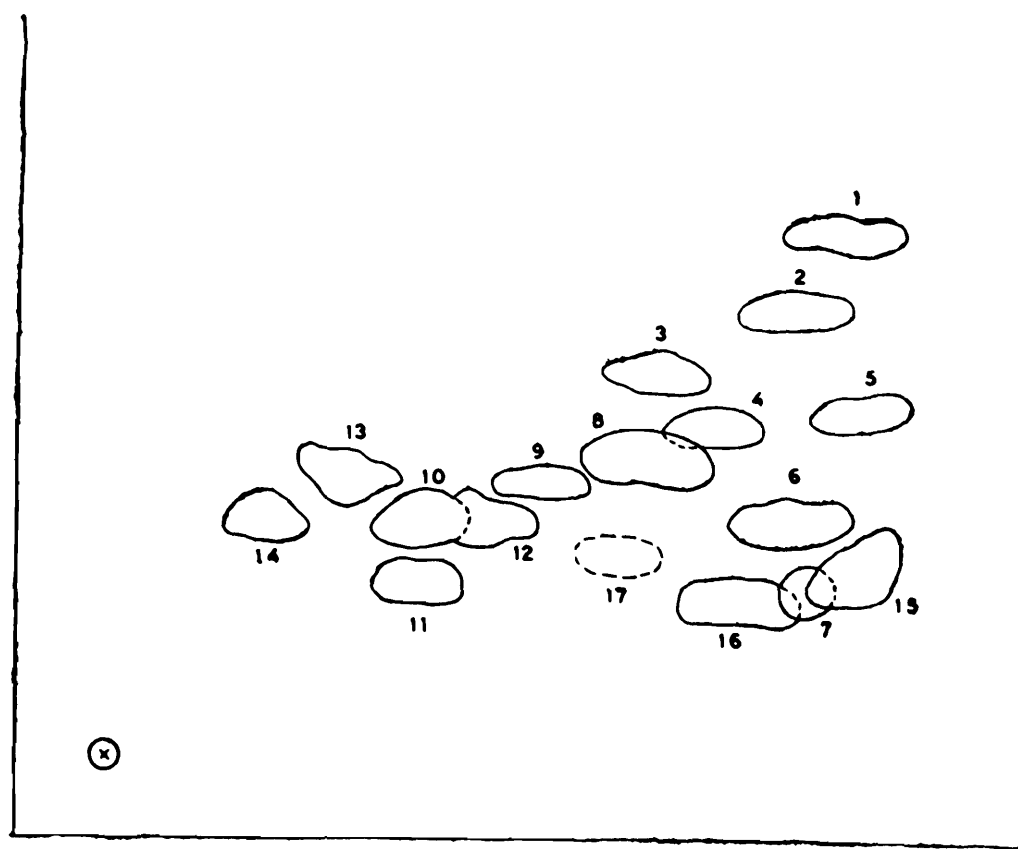


Fig. 1—Two dimensional chromatogram showing : (1) Leucine/ Isoleucine, (2) Valine, (3) Tyrosine, (4) β — alanine, (5) Proline, (6) Methionine, (7) Lysine, (8) α — alanine, (9) Threonine, (10) Glycine, (11) Asparagine, (12) Serine, (13) Glutamic acid, (14) Aspartic acid, (15) Arginine, (16) Histidine, and (17) Homoserine.

After fully drying the chromatograms again, the location of amino acids was materialized by dipping them in 0.1% solution of ninhydrin in acetone and heated in an oven at 60°C for 15 minutes.

The amino acids and amides were identified by comparing their R_f values as given in the standard literature ; and/or by visually comparing their relative positions with the chromatograms of samples of pure known amino acids and amides prepared (Fig.1) under exactly similar conditions. In the sap of many plants, a number of such compounds were also separated on the chromatograms, which could not be identified. The number of such compounds in each case was noted. No attempt was made for quantitative estimation of the various amino compounds in any case.

The study was carried out at the Division of Entomology, Indian Lac Research Institute (I. C. A. R.), Namkum, Ranchi (Bihar), during 1962-1966.

RESULTS AND DISCUSSION

The free amino-acids (including amides) present in the sap of common lac-host plants are shown in Table I, of the occasional lac-host plants in Table II, and of the non-lac-host plants in Tables III and III a.

TABLE I. Free Amino-acids and amides in some common Host-plants of the Lac insect

Amino acids/amides	<i>Butea monosperma</i>	<i>Schleichera oleosa</i>	<i>Ziziphus mauritiana</i>
α —Alanine	—	—	—
β —Alanine	—	—	+
γ —aminobutyric-acid	—	—	—
Arginine	—	—	—
Asparagine	+	—	—
Aspartic acid	+	+	+
Cystine	—	—	—
Glutamic acid	+	+	+
Glycine	+	+	+
Histidine	—	—	—
Homoserine	—	+	+
Leucine/Isoleucine	—	—	—
Lysine	—	—	—
Methionine	—	—	—
Phenylalanine	—	—	—
Proline	—	—	—
Serine	—	+	—
Threonine	—	—	—
Tyrosine	—	—	—
Valine	—	—	—
Unidentified compounds	—	2	2

+ = Present ; — = Absent

TABLE II. Free amino-acids and amides in some occasional Host-plants of the Lac insect

Amino acids/amides	<i>Albizzia lucida</i>	<i>Cajanus cajan</i>	<i>Mangifera indica</i>	<i>Samanea saman</i>	<i>Shorea roxburghii</i>
α —Alanine	+	—	—	+	—
β —Alanine	—	+	—	—	—
γ —aminobutyric-acid	+	—	—	—	—
Arginine	—	+	—	—	—
Asparagine	+	+	—	+	+
Aspartic acid	+	+	+	+	+
Cystine	—	—	—	—	+
Glutamic acid	+	+	+	+	+
Glycine	+	+	+	+	+
Histidine	—	—	—	—	—
Homoserine	+	+	+	+	+
Leucine/Isoleucine	+	+	—	+	—
Lysine	—	—	+	+	+
Methionine	+	—	—	+	—
Phenylalanine	—	+	—	+	—
Proline	?	—	—	+	—
Serine	+	—	+	+	—
Threonine	+	+	—	—	—
Tyrosine	—	—	—	+	—
Valine	+	+	—	+	—
Unidentified compounds	4	1	1	3	3

+ = Present ; — = absent ; ? = doubtful.

The last has been divided into two tables for the sake of convenience only. The number of unidentified compounds detected in each case have also been indicated in the tables.

The number of free amino acids present in the sap of *B. monosperma*, *S. oleosa* and *Z. mauritiana* are lesser as compared to that of the occasional and non lac-host plants. Here, it may be reiterated that these three plants are the main hosts for cultivation of lac on commercial scale in India. It was observed that 3 amino acids, viz., aspartic acid, glutamic acid and glycine, are present in all the three common hosts. In view of this, it may be derived that even though the amino acids essential for proper development of the lac insect are not known at present, the above 3 amino acids seem to be of primary importance. Besides these 3 amino acids, homoserine and 2 unidentified compounds were also detected in two out of three common hosts studied. The total number of identified amino acids present in the common hosts varied from 4 to 5 only (see Table I). From this observation it is

TABLE III. Free Amino-acids and amides in some Non-host plants of the Lac insect (carried over to Table IIIa).

Amino acids/amides	<i>Anthocephalus cadamba</i>	<i>Cedrela toona</i>	<i>Duranta repens</i>	<i>Dodonaea viscosa</i>	<i>Erythropsis colorata</i>	<i>Lagerstroemia thorelli</i>
α —Alanine	—	—	+	—	—	—
β —Alanine	—	—	—	—	—	—
γ —aminobutyric-acid	—	—	—	+	+	—
Arginine	+	+	—	+	+	+
Asparagine	+	—	+	+	+	—
Aspartic acid	+	+	+	+	+	+
Cystine	—	—	—	—	—	—
Glutamic acid	+	+	+	+	+	+
Glycine	+	+	+	+	+	+
Histidine	+	—	—	+	—	—
Homoserine	+	+	+	—	—	—
Leucine/Isoleucine	—	—	—	?	—	—
Lysine	—	—	—	+	—	—
Methionine	—	—	—	—	—	—
Phenylalanine	—	—	—	+	—	—
Proline	—	—	—	—	—	—
Serine	—	—	+	+	+	—
Threonine	—	—	+	+	+	+
Tyrosine	—	—	—	—	—	—
Valine	—	—	—	+	+	—
Unidentified compounds	1	—	2	1	—	1

+ = present ; — = absent ; ? = doubtful.

TABLE IIIa. Free Amino-acids and amides in some Non-host plants of the Lac insect (brought forward from Table III).

12

Amino acids/amides	<i>Lantana camara</i>	<i>Moringa oleifera</i>	<i>Syzygium cuminii</i>	<i>Swietenia macrophylla</i>	<i>Salix tetrasperma</i>	<i>Tephrosia candida</i>
α —Alanine	—	—	—	—	—	+
β —Alanine	—	—	—	—	—	—
γ —aminobutyric-acid	—	+	—	—	—	+
Arginine	—	—	—	—	+	—
Asparagine	—	—	—	—	+	+
Aspartic acid	+	+	+	+	+	+
Cystine	—	—	—	—	—	—
Glutamic acid	+	+	+	+	+	—
Glycine	+	+	+	+	+	+
Histidine	—	—	—	—	—	—
Homoserine	+	+	+	+	+	+
Leucine/Isoleucine	—	—	—	—	—	—
Lysine	—	—	—	—	—	—
Methionine	—	—	—	—	—	+
Phenylalanine	—	—	—	—	—	—
Proline	—	—	—	?	—	—
Serine	+	+	+	—	+	+
Threonine	—	—	—	—	—	+
Tyrosine	—	—	—	—	—	—
Valine	—	—	—	—	—	—
Unidentified compounds	1	1	—	—	—	1

+ = present ; — = absent ; ? = doubtful.

quite tempting to suggest that the plants which have lesser number (4 to 5) of amino acids in their sap are expected to serve as better hosts for the lac insect. But, on further analysis of results, such derivations are found to be not true. It may be seen that some plants like *C. toona*, *S. cuminii*, *M. oleifera* and *S. macrophylla* have also revealed 4 to 6 amino acids in their sap (see Tables III and IIIa), and that the three so-appearing essential amino acids (*viz.*, aspartic acid, glutamic acid and glycine) are also present in these cases, even then these plants are resistant to the lac insect.

The case of the occasional hosts is rather interesting, since some plants under this category serve as good lac-hosts in certain localities but poor in others, *e. g.*, lac is mainly cultivated on *S. saman* in Thailand but not in India ; *C. cajan* in Northeast India and *S. roxburghii* in Karnataka are good hosts, but not in other parts of India (Roonwal, 1962).

Amino acid composition of the sap of occasional hosts is varied. Whereas 6 amino acids were detected in *M. indica*, there as many as 14 were found present in *S. saman*. Besides glutamic acid, aspartic acid and glycine, homoserine was also found present in all the 5 plants studied. Asparagine was detected in 4 out of 5 plants (see Table II). All the occasional hosts studied showed 1 to 4 unidentified compounds.

Among the non-lac host plants, it was observed that the number of identified amino acids ranged from 4 to 12. In the sap of *S. macrophylla* only 4 amino acids were detected along with a doubtful presence of proline in it. Only 5 amino acids were found in the case of *C. toona*, *L. thorelli* and *S. cuminii*. This observation clashes with the assumption that plants having 4-5 amino acids in their sap are good lac-hosts as reported above.

D. viscosa contained 12 amino acids in its sap, besides one unidentified compound and a doubtful presence of leucine/isoleucine. Despite this richness in amino compounds in its sap, this plant is a non-lac-host, since it is unable to bear the lac insect for even one generation. Very few (1 to 2) unidentified compounds were detected in the sap of 7 non-hosts, while the remaining 5 have none.

Table III shows that aspartic acid, glutamic acid and glycine are present in almost all non-lac-host plants also, except the absence of glutamic acid in *T. candida*. Thus, mere presence of these 3 amino acids cannot be taken as a factor for susceptibility of the plants to the lac insect or otherwise.

Other notable finding among non-lac hosts is the presence of arginine and threonine (Table III), and of serine (Table IIIa) in most of the 6 plants in each case. Interestingly these three amino acids (*viz.*, arginine, threonine and serine) are absent in all the common lac-host plants studied, except serine in *S. oleosa*.

Homoserine was detected in 9 out of 12 non-lac host plants. Significantly it was detected in all common and occasional hosts also, except *B. monosperma*.

Conclusively, it can be inferred that the free amino acid components of the plant sap do not seem to contribute much towards the resistance or susceptibility of the plants to the lac insect.

The analysis made under the present study could not give the information regarding the factors which limit the relative performances of different plant species as lac hosts, although it looked as an aspect which could affect the lac insect and host plant interactions (Varshney, 1980). It is possible that some other compounds, like the carbohydrates, vitamins, mineral acids etc., found in the plant sap, individually or in combination with others including the amino acids, may be playing the vital role. Abiotic factors, like the climatic conditions and the soil conditions are obviously also expected to play important part as a selecting factor in determining a plant species as good lac-host.

On the basis of present study it is, however, reasonable to assume that the presence of 3 amino acids, *viz.* aspartic acid, glutamic acid and glycine, is necessary in the sap of a lac-host plant for the proper development of the lac insect.

This study also brings to light the occurrence of relatively lesser number of amino acids in the common lac-host plants. With regard to the unidentified compounds, it was seen that more number of them were met with in the common and occasional host plants than in the non-lac host plants. On the other hand, the presence of arginine and threonine in many of the non-lac host plants is also interesting, since these are absent in the sap of all common hosts examined during this study.

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**INDOPLANORBIS EXUSTUS (DESHAYES) AS THE INTERMEDIATE
HOST OF FURCOCERCOUS CERCARIAE IN WEST BENGAL**

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INTRODUCTION

In order to ascertain the impact of spreading human and animal Schistosomiasis in various parts of India a two-year (1978 and 1979) survey was conducted in 11 districts of West Bengal. The studies of Furcocercous group of cercariae have been undertaken only because the importance of this group lies in the fact that the larval forms of Schistosome parasites of man, domestic animals and birds belong to the same group.

In West Bengal Sewell in 1922 recorded 5 types of furcocercariae in Calcutta only from *Indoplanorbis exustus*. Muraleedharan (1977), Mohandas (1974) and Singh (1959) reported 5, 7 and 10 types of furcocercous cercariae in Karnataka, Kerala and Allahabad respectively. Soparker (1921) reported Furcocercariae from Bombay. Some workers studied the various groups of cercariae from their snail hosts in West Bengal but no survey-oriented works have been focussed on the furcocercal infestation in *Indoplanorbis* snails in West Bengal. The present district-wise survey has been geared up in an attempt to contribute to the knowledge on furcocercal fauna in *Indoplanorbis exustus* of West Bengal.

MATERIALS AND METHODS

The snails were collected at random from rivers, canals, streams, tanks, ponds and paddy-fields at least once in a month in 11 districts for two consecutive years, 1978-1979. The cercarial infection was carefully studied after the snails were brought alive to the laboratory and kept serially and individually in wide glass tubes each with 10 ml. of tap water and a piece of water plant on which they live. The mouths

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of the glass tubes were covered with cloth to provide intake of air and also to prevent escape of snails. The snails of the tubes had been exposed to diffused sunlight for at least 3 hours for shedding cercariae in the water-filled glass tubes. The snails, after careful examination by naked eye and magnifying glass, which shed cercariae, were isolated individually and kept in seperate glass tubes. Only those cercariae which emerged naturally from their first intermediate hosts were included in the present study. However, all snails were dissected eventually in order to locate any non-motile and immature parasitic stages. The fork-tailed cercariae were studied and identified in living condition subjected to cover glass pressure. For staining, neutral red and aceto-carmin, in very dilute solution, had been found to be very useful in elucidating the penetration gland cells, gut and genital rudiment. For excretory system, the cercariae were studied only in dechlorinated tap water. Fixation was made by means of hot (70°c) 10% formalin. At least 10 fixed specimens of mature emergent cercariae were selected for measurement. Data were collected on the date of collection, date of examination of the snails, collection areas, number of snailscollected and infected, types of cercariae involved.

Topography of West Bengal and the study area :

West Bengal is situated in the Northeastern part of India between 21° 31' and 27° 14' north latitude and 85° 51' and 89° 53' east longitude with the mighty Himalayas on the north, the Bay of Bengal on the south and the tropic of cancer running across the middle. It covers an area of 87,882 sq. kilometers having 16 administrative districts namely CALCUTTA the state capital, Bankura, Birbhum, Burdwan, Cooch-behar, Darjeeling, Howrah, Hooghly, Malda, Midnapur, Murshidabad, Nadia, Jalpaigury, Purulia, West-Dinajpur and 24-Parganas.

TABLE 1. Data on the percentage of furcocercous infection of *Indoplanorbis exustus* in different districts of West Bengal during the period from 1978-1979

Districts	Total number of snails			Total number of snails		
	collected	infected	%	collected	infected	%
	1978			1979		
Bankura	330	78	23.6%	444	89	20.0%
Birbhum	307	73	23.7%	431	82	19.0%
Burdwan	350	86	24.5%	547	103	18.8%
CALCUTTA	438	110	25.1%	677	248	36.6%
Howrah	391	101	25.8%	595	213	35.7%

TABLE 1. *Concluded.*

Districts	Total number of snails collected infected % (1978)			Total number of snails collected infected % (1979)		
Hooghly	380	94	24.7%	576	195	33.8%
Midnapur	378	93	24.6%	537	190	35.3%
Murshidabad	355	71	20.0%	517	77	14.8%
Nadia	362	81	22.3%	542	100	18.4%
Purulia	256	0	0%	376	0	0%
24-Parganas	486**	147+	30.2%*	785**	309+	39.3%*
11	4033	934	23.16%	6027	1606	26.64%

* denotes highest percentage of infection in 1978 and 1979

+ denotes highest number of snails infected in 1978 and 1979

** denotes highest number of snails collected in 1978 and 1979

Total collection : 10,060 : Total infected : 2,540 : Total % of inf. 25.25%

RESULTS

Out of 10,060 snails (*Indoplanorbis exustus*) examined, 2,540 snails have been found positive for 11 types of furcocercariae of the family Strigeidae, Schistosomatidae and other un-identified furcocercariae indicating the percentage of 25.25% (Table 1) of the total snail population. The fork-tailed cercariae recorded during the study of two-year duration but already reported from Calcutta and elsewhere were *Cercariae Iadicae* I (Sewell, 1922) ; *Cercariae Indicae* IX (Sewell, 1922) ; *Cercariae Indicae* XXVII (Sewell, 1922) ; Cercariae of *Schistosoma nasale*, Rao, 1933 ; Cercariae of *Schistosoma indicum* Montgomery, 1906 ; Cercariae of *Schistosoma spindalis* Montgomery, 1906.

The highest percentage of infection was found in the districts of 24-Parganas (30.2% in 1978 and 39.3% in 1979), Calcutta (25.1% in 1978 and 36.6% in 1979) and Howrah (25.8% in 1978 and 35.7% in 1979) respectively. Out of 11 types of furcocercariae 6 have been reported earlier and the 5 of them have been considered to be completely new species. Of the five new species two of them belong to the family Strigeidae two of them belong to the family Schistosomatidae and the other one has been included in un-identified group of furcocercariae. District-wise survey revealed that the peak infection periods were June, July, August and September in 1978 and July, August in 1979. Most of the cercariae were found abundantly excepting the schistosome cercariae. Infection with furcocercous cercariae was found negative in Purulia district.

Double, multiple and mixed infections with various kinds of cercariae in the individual snail were observed in *Indoplanorbis exustus* (Deshayes) by many authors like Sewell (1922), Bhalerao (1943), Peter (1954), Singh (1959), Jain (1970), Sahai (1969-70), Mohandas (1971), Muraleedharan (1977) and Soparker (1921). Here in two cases of double infection one case with Cercariae of *Schistosoma spindalis*, Montgomery, 1906 with *Cercariae Indicae* XVII (a small form xiphidiocercous cercariae Sewell, 1922) was found in 3 snails (0.5%) of Howrah district in 1979. Another case of double furcocercous cercarial infection with cercariae of a new Schistosome with *Cercariae Indicae* IX (Sewell, 1922) was found in 2 snails (0.2%) in Calcutta (Dum-Dum area) in 1979.

DISCUSSION

Indoplanorbis exustus (Deshayes) is the most common freshwater gastropod of West Bengal as found in other parts of India acting as the common intermediate host of many trematode parasites. The data clearly indicates that in West Bengal *Indoplanorbis exustus* was found to be carrying a large number of furcocercarial burden and many types of fork-tailed cercariae seem to adapt easily *Indoplanorbis exustus* as an intermediate host. The observation is in conformity with the findings of Singh (1959) in U. P., Mohandas (1974) in Kerala and Muraleedharan (1977) in Karnataka. It also appears that the percentage of infection with furcocercariae in *Indoplanorbis exustus* is more or less higher in West Bengal.

Considering the percentage in seasonal basis in different districts it is quite clear that the percentage of infection was higher in ponds in the rainy season than in the summer time. Infection with the cercariae of *Schistosoma nasale*, Rao, 1933 was found to be fairly good in July and August in the waterlogged paddy-fields of 24-Parganas, Nadia and Howrah in both the years. Sewell (1922) found that percentage of infection varied from place to place. Wesenberg-Lund (1934) remarked that the percentage of infection was high in ponds than in lakes. Belyakova-Butenko (1971) observed in Khazakhstan that larval trematode infection fluctuated very much in lakes, ponds and rivers. The seasonal changes in infection rates with furcocercous cercariae were indicated by Kemp and Gravely (1919), Probert (1966), and Singh (1959). Singh (1959) observed two peaks in *Indoplanorbis exustus* infected with 4 species of furcocercous cercariae. Mukherjee (1966) recorded high incidence of infection in rainy season and also in winter season in 5 molluscan

species. This survey carried out in West Bengal will definitely focus the importance of snail species in spreading trematodes and the diseases caused by them among human, domestic animals, birds and fishes etc. The informations collected in the given data could be used in co-operating controlling measures against the havoc of Helminth diseases.

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*not seen original.

SOME ABERRANT ASPECTS OF PLANT ENVIRONMENT IN RELATION TO INSECTS

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INTRODUCTION

The theme of this Seminar is '*Host as environment*', and the topic of this presentation : "*Some aberrant aspects of plant environment in relation to insects*". Broadly, in this paper curious or aberrant plant environment, has been dealt, in which insects are attracted towards, and captured in some part of the plant. They are killed and absorbed. This plant part is usually a full, or part of a leaf, modified in shape or provided with special structures and mechanism for the purpose.

Before describing this, a few words about the term—*Host*.

The dictionary meanings of Host are (1) One who *entertains* a stranger or guest at his house without reward ; or (2) an organism on which another lives as a parasite.

In carnivory, surely there is no entertainment for the guest, and certainly insects involved in *this* curious animal-plant relationship do not live, as long as the poor things do live on their host, as parasites.

It is for this reason that the environment provided by the plant to the captured insects can be called as aberrant.

It is common knowledge that normally and mostly plants provide food for animals. It is only in these carnivorous plants where the situation is reverse and animals provide or supplement food of some plants.

CENSUS

Out of a total of over 200,000 species of higher plants, about 400 are carnivorous. They belong chiefly to 5 families and 12 genera. These are represented in India by 3 families, 5 genera and *ca.* 35 species. Genera found in India are marked with (*).

NEPENTHACEAE (1 genus)

**Nepenthes*—Out of *ca.* 70 species distributed in Old World Tropics, only one is known from India, namely, *N. khasiana*, which is endemic to India. It is a climbing or prostrate undershrub. Its

demand for museum and teaching material has depleted natural populations and the plant has been declared as a threatened species. It's export is banned.

SARRACENIACEAE (3 genera)

Sarracenia—10 species in Atlantic North America. The entire leaf forms the pitcher. All leaves form the pitcher. Mouth has honey glands, then slidezone, zone of hairs, and at bottom is the fluid where insects are drowned.

Heliamphora—ca. 5 species in North-West and South America.

Darlingtonia—1 species found in California ; it has pitcher like *Sarracenia*, but the top of tube is bent over and forms fish-tail-shaped flap in front.

CEPHALOTACEAE (1 genus)

Cephalotus—1 sp. South-West Australia. Leaves of 2 kinds, lower rosette-like and pitcher-shaped ; upper flat, green.

DROSERACEAE (4 genera)

**Drosera*—ca. 100 species in tropical and temperate regions. Usually herbs. Leaves have tentacles, these have swollen reddish heads, which secrete glistening fluid. Insects mistake it for honey and are held by it.

Three species in India : *D. burmanii* Vahl throughout India ; *D. peltata* Sm. common on hills.

Drosophyllum (1 species) South-West Europe, North Africa. Functions like *Drosera*.

Dionaea—1 species. East and North America. Venus Fly Trap.

**Aldrovanda*—1 species. Central Europe. Central Asia, Africa, East and South-east Asia, Australia. A root-less swimming plant. Leaf has a blade like *Dionaea*, and reported from Bengal and Manipur.

LENTIBULARIACEAE (3 genera)

**Pinguicula*—ca. 40 species. Northern hemisphere including Himalayas. Leaves covered with glands, some sessile, some stalked. One species in India—*P. alpina* L. Alpine Himalayas.

Genlisea—15 species. Central and South America, Africa.

**Utricularia*—ca. 150 species in tropical and temperate regions, later all aquatic. Insects sucked in, due to sudden expansion of

bladder. 30 species in India. Five are rootless aquatics, 4 epiphytes and 21 terrestrial on marshy or moist soil.

HISTORICAL

The phenomenon of insects being attracted towards and caught in the lobes of leaves of *Dionaea* or *Drosera* or in pitchers of *Sarracenia* was observed around middle of 18th century but the thought that insects contributed to the nutrition of their host plants was not suspected or described till later part of 18th century when D. Diderot (between 1774-1780) used the term carnivory for it.

Till middle of 19th century, no actual experimental work was done to prove or contradict carnivory, or that plants really drew any nutrition from the captured insects.

Charles Darwin conducted many experiments for about two decades and published the first ever comprehensive work on insectivorous plants in 1875. He established that plants did derive nutrition from captured insects.

DEVICES FOR ATTRACTING AND CAPTURING INSECTS

Ornamental colours or scent of the pitchers, particularly of their lids or portions near mouth and secretions on glands of leaves attract insects.

The capture devices are either active or passive :

Active :

Snap Trap : In *Aldrovanda* and *Dionaea* the excitation of trigger hairs on dorsal surface of leaf causes loss of turgidity of special cells on ventral surface near the midrib and the closure of leaves.

Suction Trap : In *Utricularia* the insects are sucked into the bladder by sudden inflation of bladder.

Passive :

Pitfall or pitcher trap : *Nepenthes*, *Sarracenia*, *Darlingtonia*, *Heliamphora*, *Cephalotus*.

Sticky glands : *Drosera*, *Pinguicula*, *Drosophyllum*. In *Genlisea* the leaves are bifurcating and sub-terranean and resemble hollow tubes. On the inner surface they have digestive glands and alternating

downward pointing bristles. Water with soil particles and insects enters the tube, and the insects are digested. The flow is maintained by secretion of water from the walls of the tube. There is a utricle at the base of each leaf ; in this utricle accumulate the undigested remains of insects.

DIFFERENT KINDS OF GLANDS

The glands found on several plant parts are of different kinds.

Alluring—These are similar to nectaries and secrete sugary, scented fluids. In some species of *Sarracenia* the glands provide sweet trail from ground to lip of pitcher. Ants follow the trail and are drowned.

In *Utricularia*, sessile glands seem only to pump out water.

Secreting enzymes—The secretory head may have few cells (as in *Lentibulariaceae*) or several hundred cells (as in *Drosera*). In pitcher-plants gland-heads are sunken in leaf tissue and even protected by epidermal flaps. In leaf-trapping species, e.g. *Drosera* and *Pinguicula*, glands are usually stalked.

PHYTOGEOGRAPHY AND ECOLOGY

In India, carnivorous plants are terrestrial as well as aquatic. *Aldrovanda* is wholly aquatic. *Utricularia* species in India are rootless aquatics or epiphytic, or they grow on wet ground and rocks ; sometimes they are twining. *Nepenthes* and *Pinguicula* are terrestrial. *Drosera* is terrestrial but mostly in marshy or wet ground.

Most carnivorous plants grow in habitats which are nutrient-poor.

They grow in very restricted areas, and in addition to the pitcher plant many other species are threatened.

Two other uncommon genera of plants which provide somewhat curious environment to insects are *Dischidea* and *Hydnophytum*. Here the plants serve only as hosts but do not seem to benefit or suffer from the presence of insects.

Dischidea (Asclepiadaceae)—4 species in India.

D. rafflesiana has 2 kinds of leaves—Ordinary and pitcherlike. Adventitious roots from stem or petiole develop into the pitcher which is ca. 20 cm deep. Rain-water collects in pitcher for good growth of roots. Insects nest in the pitcher. Inside walls of leaves are waxy, hence the leaves do not absorb the moisture ; it is available to roots only.

In *Hydnophytum* the tubers harbour innumerable ants. *H. fornicarium* is found in Andamans.

The biology of all these plants needs to be studied. Why are most of them so rare and restricted in distribution? Are they very choosy about their microclimatic environment? Or, does the distribution of insects which fall prey to them and supply nutrition to them, contribute to their rarity? The author has deliberately not tried to say anything about the families or genera of insects associated with the plants described here, as the zoologists would certainly be knowing about this aspect much more.

The above account is a brief review of this interesting group of host plants providing a very unusual environment to insects, with examples from India and in a few cases from other countries.

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EPIZOOTIC DISEASE OF THE GIANT AFRICAN SNAIL
ACHATINA FULICA BOWDICH

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INTRODUCTION

While surveying the distribution and present status of the giant African land snail *Achatina fulica* Bowdich in India special attention was given to its predators and parasites so as to find out an effective controlling device. Interestingly, the leucodermia-like disease syndrome was observed in the wild snail population occurring in different parts of India, and the same is described in this paper.

MATERIAL AND METHODS

In each snail infested area the population density of the snail was estimated in the same technique as mentioned earlier by Raut (1979). From those snails the number of infected snails were counted and measurements of their shell length were noted. The snails were, then, grouped into three size groups viz. 8 mm to 30 mm, 31 mm to 60 mm and 61 mm to above to understand whether the causative agents have any preference to a particular size group of the host. The infected snails were again categorised into different groups based on their site of infection. As the disease is characterised particularly by leucodermic lesions on the tentacles, snout, face and foot the infected snails were counted as per their site of infection. But the individuals having infection more than one sites were termed as 'polysitic infection' and counted separately. Data on temperature humidity and rainfall were supplied by the meteorological stations of the Government of India.

OBSERVATION

Locality vs. infection :

Of the 19 localities viz. Calcutta, Coochbihar and Midnapore of West Bengal ; Gauhati and Jorhat of Assam ; Dimapur of Nagaland ; Nongpoh of Meghalaya, Imphal of Manipur ; Darbhanga, Katihar and Chaibasa of Bihar ; Balasore, Baripada and Anandpur of Orissa ; Moradabad of Uttar Pradesh ; Madras and Annamalai Nagar of Tamilnadu and Palghat and Calicut of Kerala surveyed the disease syndrome has been observed in 17 localities. No symptom of

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leucodermia-like disease was observed among the snails occurring in and around Madras and Nongpoh. Of the 17 localities, infection was recorded maximum, 46.12% at Calicut and minimum, 28.66% at Darbhanga. Fig. 1 shows the number of infected snails out of observed specimens occurring at different localities of India. It is observed that the rate of infection is higher where population density of the host is higher. As the population density of *A. fulica* and the rate of infection showed a marked variation from area to area some important abiotic factors like temperature, humidity and rainfall of the areas concerned were taken into consideration (Fig. 1) to understand the

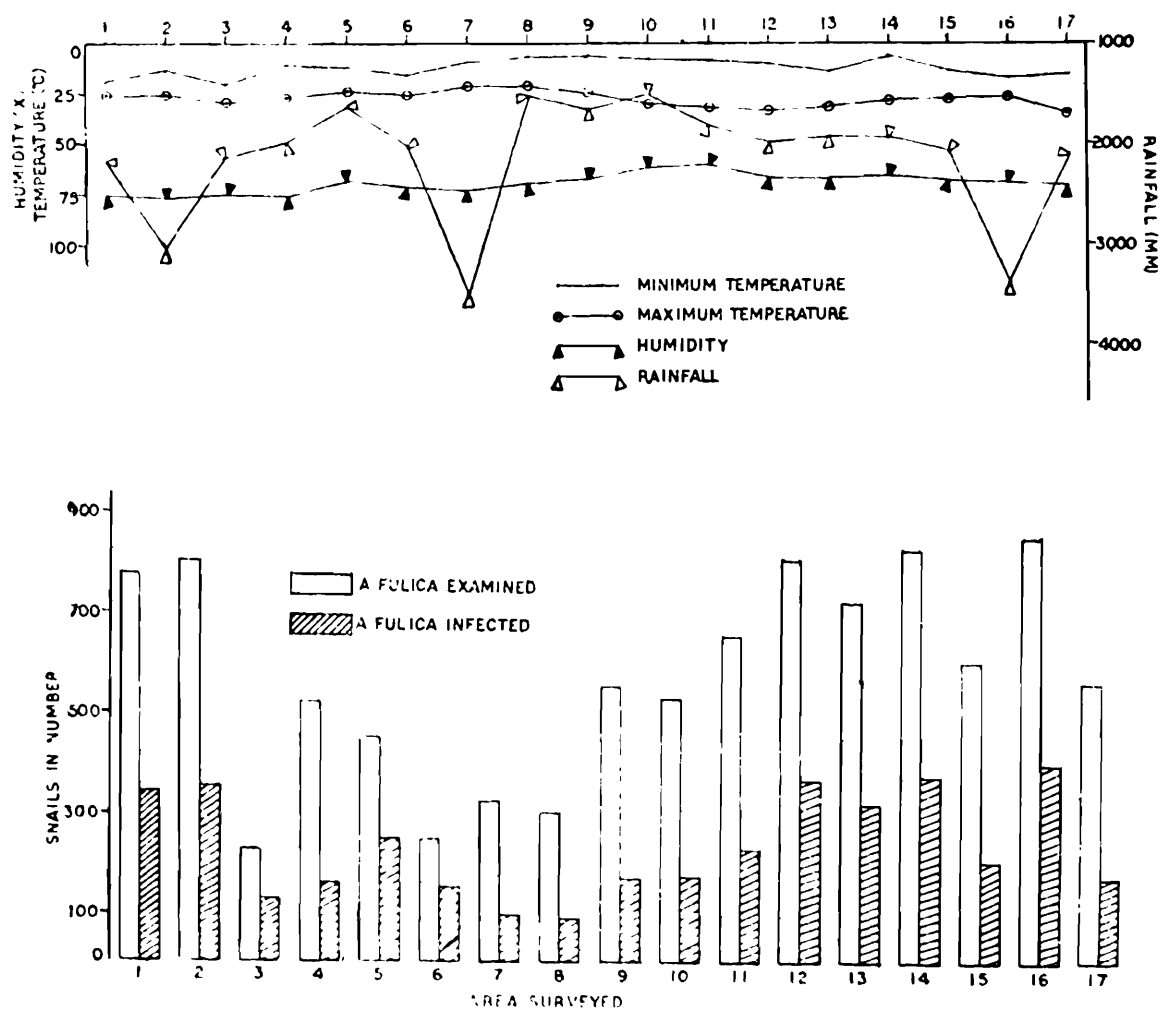


Fig. 1. Rate of leucodermic infection in 17 different *Achatina* populations in India with temperature, humidity and, rainfall of the areas concerned. (1 Calcutta, 2 Coochbihar, 3 Midnapore, 4 Gauhati, 5 Dimapur, 6 Jorhat, 7 Imphal, 8 Darbhanga, 9 Katihar, 10 Chaibasa, 11 Balasore, 12 Baripada, 13 Anandpur, 14 Moradabad, 15 Palghat, 16 Calicut 17 Annamalai Nagar)

influence of those factors, if any, on the dispersal and out-break of the disease. It is also evident that the intensity of infection is influenced:

by a mean maximum temperature range 22 to 32°C and a mean minimum range 12 to 18°C, a mean humidity range 70 to 90 and 1200 to 2500 mm rainfall as shown in Fig. 1.

Size group vs. infection :

In nature, snails of different size groups are found in the same habitat side by side. Measurements of the shell length of all the infected snails of a particular habitat suggest that the snails of all size groups are susceptible to infection. However, it is observed that the causative agents have a definite preference for the juvenile snail-hosts i.e. 31 mm to 60 mm size group, which is evident from the rate of infection in 17 different host-snail populations thriving almost in different biogeographical conditions.

Altogether, a total of 10,338 snails comprising three different size groups were examined and among them 3935 (38.07%) were observed

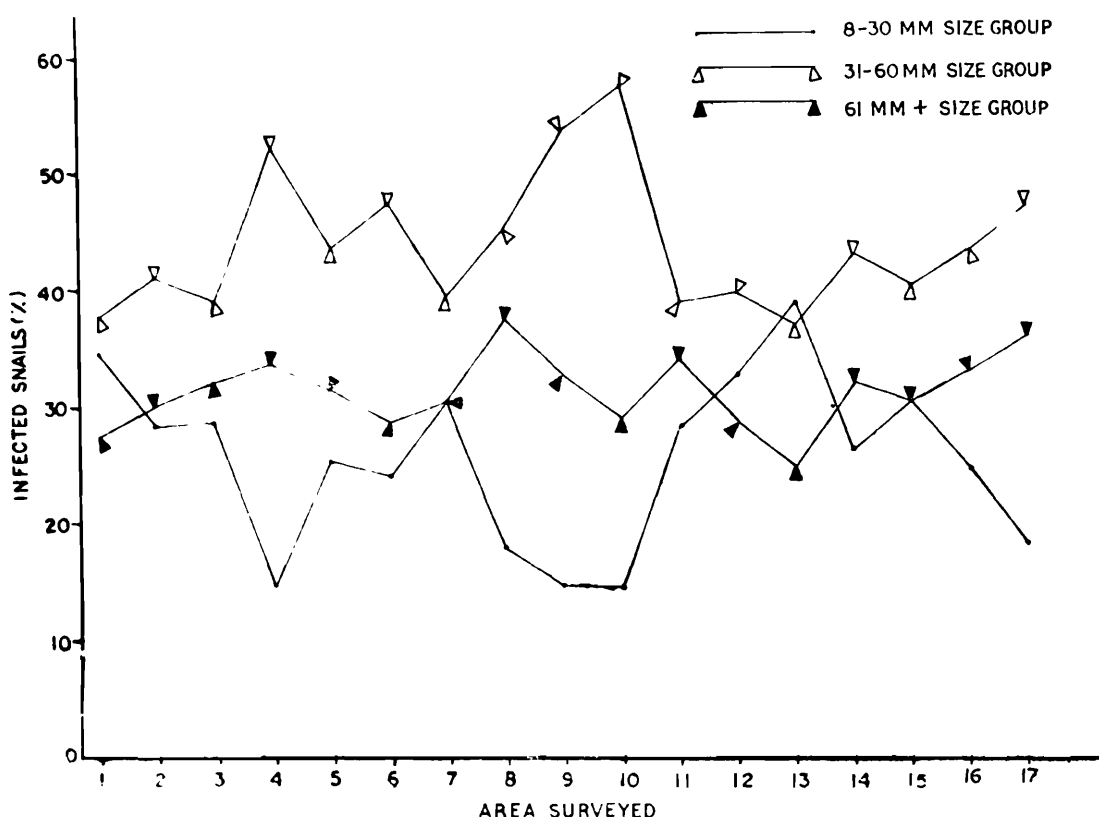


Fig. 2. Rate of leucodermic infection in different size groups of *A. fulica* of 17 different localities. (For explanations of areas surveyed please see Fig. 1).

with leucodermic lesions. Of the 3935 infected snails 1049 (26.65%) were between 8 mm to 30 mm size group, 1683 (42.75%) were between

31 mm to 60 mm size group and 1203 (30.56%) were between 61 mm to higher size groups. The infection rate in three different size groups of snail recorded from the 17 localities has been plotted in Fig. 2. It is clear that the infection rate in 31 mm to 60 mm snails is almost constant throughout while the snails of higher and lower size groups showing the rate of infection variable with the locality.

Size group vs. site of infection :

The disease syndrome was observed in tentacles, snout, face and foot of the snails. Of the 1049 snails of 8 mm to 30 mm size group 472 (44.99%), 205 (19.54%), 111 (10.58%) and 103 (9.81%) had leucodermic lesions in the tentacles, snout, face and foot respectively while 158

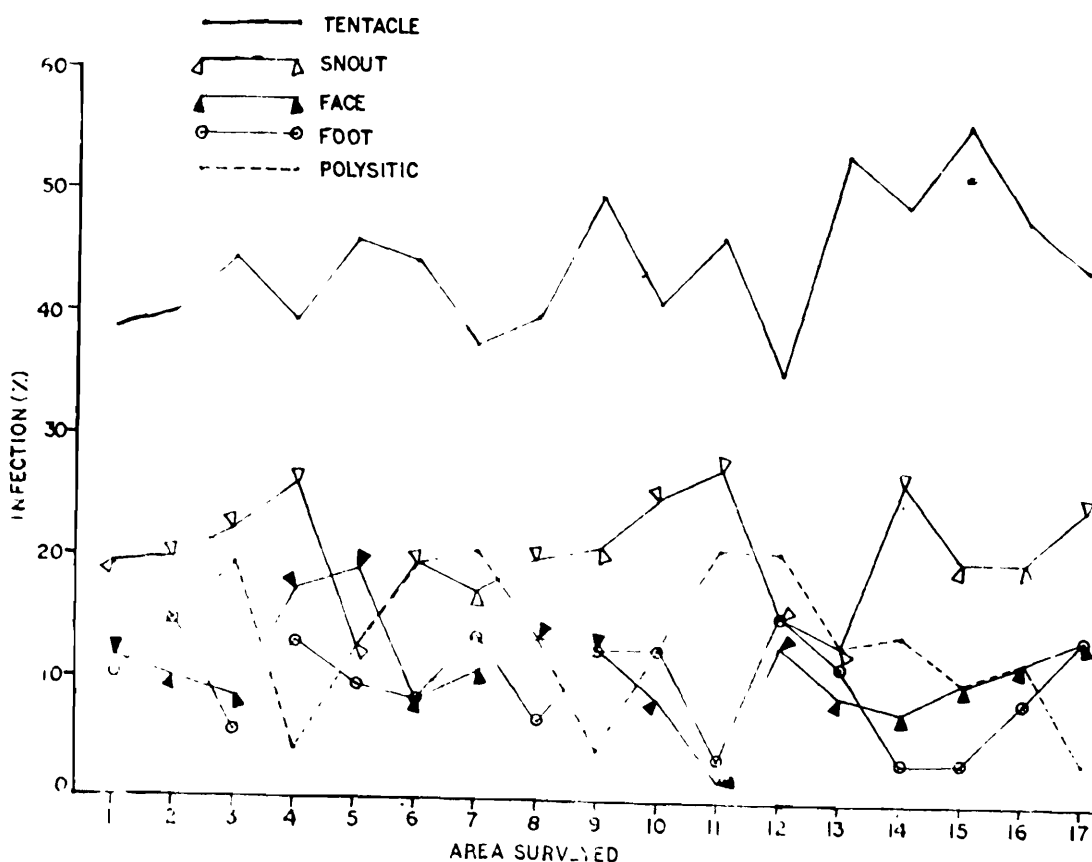


Fig. 3. Variations in the rate of leucodermic infection to different sites of *A. fulica* of 8 mm to 30 mm size group of 17 localities (For explanations of areas surveyed please see Fig. 1).

(15.06%) individuals showed 'polysitic infection.' The variation in infection rate to different sites in the snails of 8 mm to 30 mm of the 17 stations have been shown in Fig. 3. Tentacles of the snails of 31 mm to

60 mm size group showed higher infection rate than that of the younger size group. Out of 1683 snails, 600 (11.17%), 240 (14.26%), 163 (9.68%) and 188 (11.17%) showed infection in tentacles, snout, face and foot respectively. The percentage of snails with 'polysitic infection' was 29.23. Fig. 4 shows the variation in percentage of infected snails

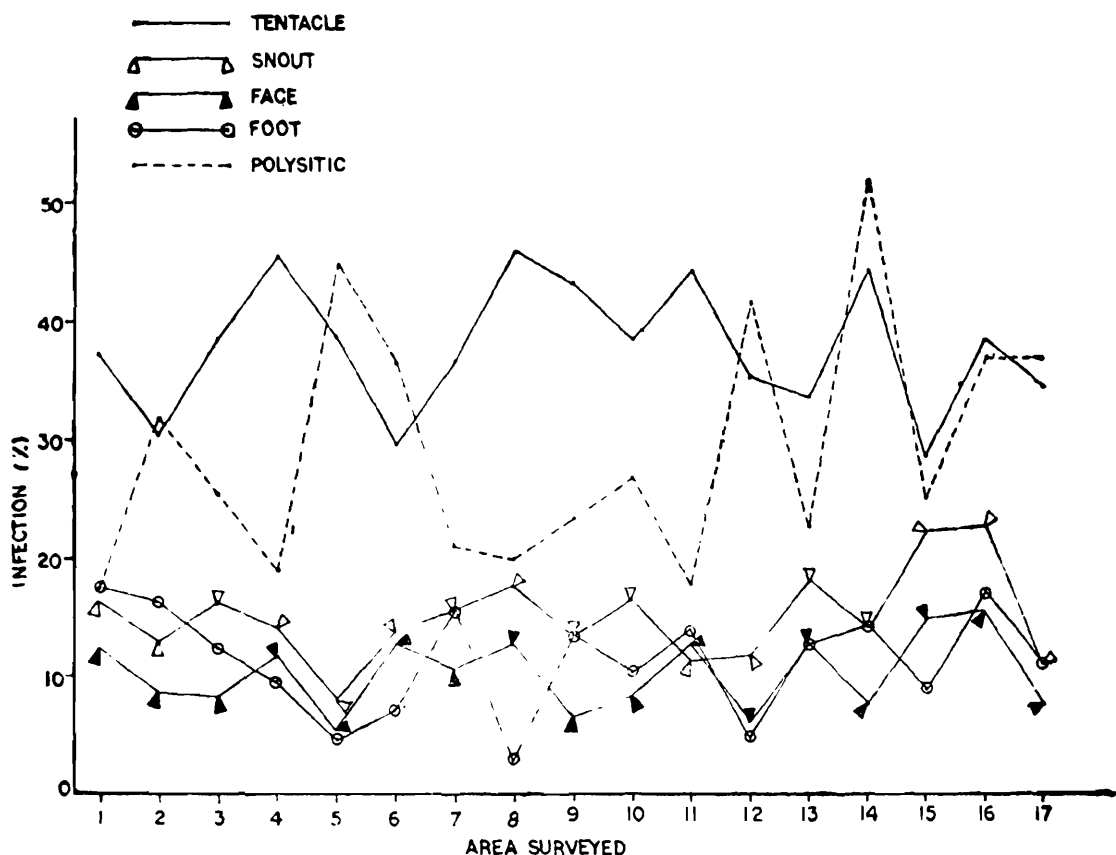


Fig. 4. Variations in the rate of leucodermic infection to different sites of *A. fulica* of 31 mm to 60 mm size group of 17 different localities (For explanations of areas surveyed please see Fig. 1)

at different sites of the host-snails of 31 mm to 60 mm size groups. Interestingly, in 61 mm and above size group, out of 1203, 462 (38.40%) snails showed 'polysitic infection' while 381 (31.67%), 170 (14.13%), 99 (8.22%) and 91 (7.56%) individuals were found infected through tentacles, snout, face and foot respectively. The rate of infection to

different sites of the snails of 61 mm and above size group studied from different localities has been shown in Fig. 5.

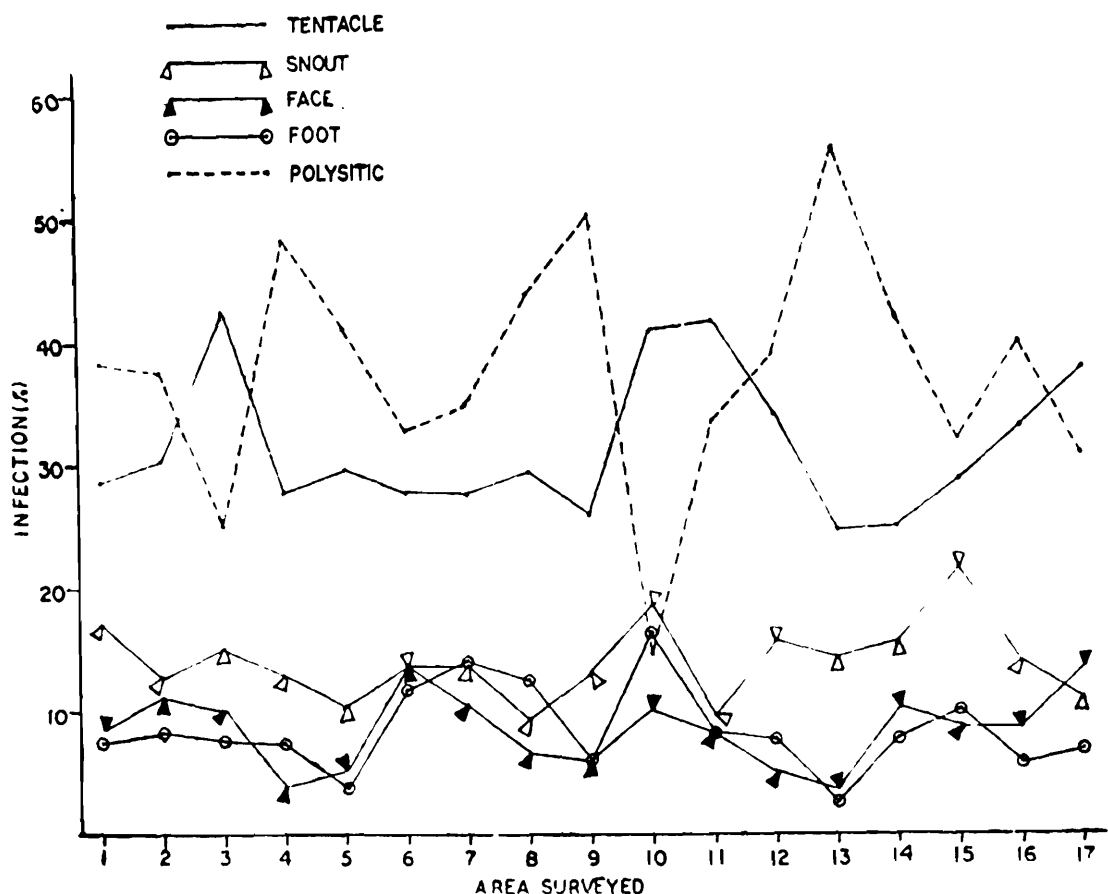


Fig. 5. Variations in the leucodermic infection rate to different sites of *A. fulica* of 61mm and above size groups of 17 localities (For explanations of areas surveyed please see Fig. 1).

DISCUSSION

A number of workers reported the occurrence of leucoderma-like disease in the giant snails from different countries of the Indo-Pacific islands (*vide* Mead, 1961). In India, Srivastava (1966) and Raut and Ghose (1977) reported the same disease from central and eastern Indian States respectively. Dean *et al.* (1970) isolated the bacterium *Aeromonas liquefaciens* from such diseased snail from Hawaii.

Present observations on the outbreak of the disease in *A. fulica* in different environmental conditions of India suggest that the climate suitable for the host's survival is favourable for the parasites also. No disease symptom in achatina population of Madras and Norgpoh areas may be attributed by the fact that the disease is occurring in those areas but in the periods while surveys were conducted it was not manifested at all. Higher infection rate at Calicut and lower infection rate at

Darbhangha are most probably related with the variations in the amount of rainfall, and also on the number of rainy days as the snails remain active with the rains. This offers more suitable conditions for the contamination of the disease. And the frequency of contamination is dependent on the density of snail population which is evidenced from the present observations on the rate of infection in relation to the density of host population.

The disease phenomenon is more interesting because in spite of different environmental conditions in the *A. fulica* infested areas of India as well as in other parts of the globe the causative agent did not facing any such kind of environmental stress that would stop its activity. It is important to note that the snail population is largely governed by the climatic factors which has already been discussed by Raut (1979). But it is interesting that the host population though sometimes subject to adverse climatic conditions offer, to some extent, suitable media for the growth and development of causative agent, or in other words the causative agents are able to change their habit rapidly in different conditions. However, whatever be the possible factors it is only the host's environment that influencing the causative agents for rapid multiplication and successful propagation.

In general, the tentacles are subject to first victim of the parasites and the snout, face and foot are next in order. It is probable that the tentacles of different snails are usually come in contact with each other during feeding and the percentage of infection is accordingly higher. But comparatively the more higher rate of infection in tentacles and other parts of the snails of 30 mm to above sizes is associated with the fondle, caress and licking up of all the sites during courtship as the snail attain sexual maturity between 52 mm to 60 mm shell size.

The story regarding the dispersal of giant African snail tells that the snail was introduced in Calcutta (India) in 1847 from Mauritius. And a disease was first recorded here in Calcutta (Annandale, 1919). South (1926) accepted Annandale's report and remarked about the disease as one of the controlling factors of *A. fulica*. In 1947 Daniel B. Langford suspected some disease syndrome in achatina populations in the Pacific Islands (*vide* Mead, 1961). Interestingly Langford introduced the diseased snails of Koror into the achatina populations in Oahu and Anigua. In 1950 Kondo reported the same disease syndrome in *A. fulica* from Anigua. Mead (1961) while examining the snail population in Oahu in 1955 did not find any evidence of the

disease syndrome. Reports on the leucodermic lesions suggest that the disease is a common one and is being carried by the snail-hosts from area to area in course of their dispersal as is evidenced by the similar type of disease syndrome as well as common sites for infection reported subsequently by Van Zwaluwenburg (1955) from Bangkok, Thailand, Singapore, Hongkong and Hawaii, by Mead (1955, 1961) from Ceylon and by Srivastava (1966) and Raut and Ghose (1977) from India.

From the foregoing discussion it may be concluded that the present strain of causative agent would not be able to control the giant snail population because of long host-parasite association. But the possibility of the control of this nefarious pest by a "virulent strain" of the causative agent to be produced in laboratory could not be denied.

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A CRITIQUE TO THE STUDY OF TERMITE FLAGELLATES FROM INDIA IN RELATION TO THEIR HOSTS

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INTRODUCTION

First publication of termite flagellates from India dates back to 1890 when Simons published a brief account of two flagellates from termites of Calcutta, West Bengal. But in that description no generic nor specific names of those flagellates or hosts were mentioned. Even no drawing was produced for them nor any detailed account sufficient for determining their systematic position was given. Simons also studied some "Behar termites" (*loc. cit.* Kirby 1932) which, as he found, were not infected by protozoa.

Then after a long gap Imms (1919) described 2 new species of flagellates, namely, *Trichomonas termites* and *Trichonympha pristina* from *Archotermopsis wroughtoni* (Desneux). Cutler after obtaining a living stock of these termites carried on further studies and redescribed (1919, 1921) them as *Ditrichonympha termites* (now known as *Trichomitsopsis termites* (Imms) Honigberg) and *Pseudotriconympha pristina* (now known as *Protrichonympha pristina* (Imms) Saleem) respectively. In addition to these he (1920) also described one new genus *Joenopsis* from the same host to accommodate 2 species, *J. polytricha* and *J. cephalotricha* (now known as *Parajenopsis cephalotricha* (Cutler) Saleem) and another new species *Macrojania axostylis*.

From 1919 to 1949 De Mello and his collaborators published series of papers on termite flagellates contributing the following 45 species and 4 varieties. Many of his species are synonymised ; so the current name against each concerned species is indicated for the convenience of further discussion.

a. Species described by De Mello

Original name	Synonymed as
1. <i>Pyrsonympha grassit</i>	<i>Holomastigotoides grassii</i>
2. <i>Tricercomitus damasmorai</i>	—
3. <i>T. sockheyi</i>	—

Original name	Synonymed as
4. <i>Hexamastix indica</i>	<i>Holomastigotoides grassii</i>
5. <i>Devescovina gyrinoides</i>	—
6. <i>Stephanonympha reenstiernai</i>	—
7. <i>Trichomonas costulata</i>	—
8. <i>Leidia annandelei</i>	<i>Holomastigotoides hemigymnum</i>
9. <i>L. kempi</i>	
10. <i>Holomastigotoides hartmanni</i>	
indica	
11. <i>L. campanula</i>	<i>H. campanula</i>
12. <i>L. metchnikovi</i>	<i>Spirotrichonympha flagellata</i>
13. <i>Holomastigotoides hartmanni</i>	<i>H. mirabile katiawarensis</i>
<i>katiawarensis</i>	
14. <i>H. koidzumii</i>	—
15. <i>H. gigas</i>	—
16. <i>H. globosus</i>	—
16a. <i>H. globosus britoi</i>	—
17. <i>H. piriformis</i>	—
18. <i>H. inexpectatus</i>	—
19. <i>H. reniformis</i>	—
20. <i>H. sphaeroidalis</i>	—
21. <i>H. ogivalis</i>	—
22. <i>H. operculatum</i>	—
23. <i>Spirotrichonympha coimbatorensis</i>	—
24. <i>S. leidy</i> var. <i>leucotermes indicola</i>	<i>S. leidy</i>
24a. <i>S. leidy damanensis</i>	—
25. <i>S. mirabilis indica</i>	—
26. <i>S. ovoidea</i>	—
27. <i>S. rotunda</i>	—
28. <i>Trichonympha flecheri</i>	—
29. <i>Pseudotrichonympha belari</i>	—
30. <i>P. hertwigi simplex</i>	—
31. <i>P. ramani</i>	—
31a. <i>P. ramani seminuda</i>	—
b. Species described by De Mello and De Brito	
32. <i>Devescovina cometoides</i>	—
33. <i>D. damanensis</i>	<i>D. lemniscata</i>
34. <i>D. kirbyi</i>	<i>partim Foaina nana</i> and <i>partim F. solita</i>
35. <i>Metastephanonympha perronciti</i>	<i>Stephanonympha perronciti</i>

c. Species described by De Mello & De Mello

- | | | |
|-----|-------------------------------------|------------------------------------|
| 36. | <i>Proboscidiella hoffmanni</i> | <i>Microrhopaloidina hoffmanni</i> |
| 37. | <i>Holomastigotoides cingulatum</i> | |
| | <i>coimbatorensis</i> | — |
| 38. | <i>H. mirabile margabhandui</i> | — |
| 39. | <i>H. proboscifer</i> | — |

d. Species described by De Mello and Montero, G.

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|-----|--------------------------------------|---|
| 40. | <i>Strobilonympha serpentiformis</i> | } <i>Polymastigoides</i>
<i>elongata</i> |
| 41. | <i>S. schizophyla</i> | |
| 42. | <i>S. pisciformis</i> | |

e. Species recorded by De Mello

- | | | |
|-----|---|---|
| 43. | <i>Tricercomitus divergens</i> Kirby | — |
| 44. | <i>Holomastigotoides hemigynum</i> Grassi | — |
| 45. | <i>Spirotrichonympha elongata</i> Grassi | — |
| 25a | <i>S. mirabilis</i> Grassi | — |

Kirby (1932) examined some alcohol preserved termite specimens of *Anacanthotermes macrocephalus* (Desneux) from India and recorded the occurrence of *Trichonympha turkestanica* Bernstein. He also observed some poorly preserved forms of *Holomastigotoides* Grassi and Foà, *Holomastigotes* Grassi, *Microspironympha* Cleveland *et al.* and *Stephanonympha* Janicki but could not identify them upto specific level.

Karandikar and Vittal (1954) recorded 16 species of flagellates including 7 new ones, viz., *Holomastigotoides dharwarensis*, *H. rayi*, *Spirotrichonympha froilanoi*, *S. karnataki*, *Pseudotrichonympha cardiformis*, *P. pisciformis* and *P. subapicalis* from the gut of *Coptotermes heimi* (Wasmann) and *Heterotermes malabaricus* Snyder. Chakravarty and Banerjee (1956) described 3 new species, *Holomastigotoides bengalensis*, *Spirotrichonympha pyriformis* and *Pseudotrichonympha indica* from an unidentified termite species of *Heterotermes* collected from Calcutta. Uttangi (1959, 1962) examined gut contents of *Heterotermes indicola* (Wasmann) and *Coptotermes heimi* from Dharwar and described 8 new species, viz., *Holomastigotoides elongata*, *H. magnus*, *H. melloi*, *H. ovalis*, *H. saccusiformis*, *H. turboformis*, *H. visnagarensis* and *Trichonympha gujarathensis*.

From 1972 to 1977 Das has made a detailed study of flagellate symbiotes of 4 termite species from West Bengal recording 28 species of flagellates including 8 new ones, viz., *Oxymonas bengalensis*, *O. bosei*,

Devescovina steni, *Stephanonympha minuta*, *S. pyriformis*, *Holomastigotoides hollandi*, *H. emersoni* and *Spirotrichonympha roonwali*. Tiwari (1977, 1978) also published one new species of flagellate, *Spirotrichonympha bhadreshwarensis* and recorded a few flagellate species from termites of West Bengal.

Thus in India 8 species of lower termites, namely, *Neotermes bosei* (Snyder), *Cryptotermes havilandi* (Sjöstedt), *Anacanthotermes macrocephalus* (Desneux), *A. viarum* König, *Archotermopsis wroughtoni* (Desneux), *Coptotermes heimi* (Wasmann), *Heterotermes* (= *Leucotermes*) *indicola* (Wasmann), *H. malabaricus* Snyder and a few termite species of uncertain taxonomic status have been studied for their symbiotes and 78 species and 6 varieties of flagellates (Table 1) have been recorded so far. These works are insignificant comparing to those of the other parts of the globe. Still they deserve critical consideration as discussed below.

TABLE 1. Systematic list of flagellate symbiotes from Indian termites

- Order : POLYMASTIGIDA
 Family : OXYMONADIDAE Kirby
 Genus : *Microrhopalodina* Grassi & Foa
 = *Proboscidiella* Kofoed & Swezy
 1. *M. hoffmanni* (De Mello & De Mello)
 = *Proboscidiella hoffmanni* De Mello & De Mello
 Genus : *Oxymonas* Janicki
 2. *O. bengalensis* Das
 3. *O. bosei* Das
 4. *O. grandis* Cleveland
 5. *O. parvula* Kirby
 Order : TRICHOMONADIDA
 Family : MONOCERCOMONADIDAE Kirby
 Genus : *Hexamastix* Alexeieff
 6. *H. indica* De Mello
 Genus : *Tricercomitus* Kirby
 7. *T. damasmorai* De Mello
 8. *T. divergens* Kirby
 = *Pyrrsonympha havilandi* Das
 9. *T. sokheyi* De Mello
 Family : DEVESCOVINIDAE Doflein
 Genus : *Devescovina* Foa
 10. *D. cometoides* De Mello & De Brito
 11. *D. glabra* Grassi
 12. *D. gyrinoides* De Mello
 13. *D. lemniscata* Kirby
 14. *D. steni* Das

TABLE 1. *Contd.*

- Genus : *Foaina* Janicki
15. *F. nana* (Kirby)
= *Devescovina kirbyi* De Mello & De Brito (Partim)
 16. *F. reflexa* Kirby
 17. *F. solita* Kirby
= *Devescovina kirbyi* De Mello & De Brito (Partim)
- Genus : *Polymastigoides* Grassi & Hollande
18. *P. elongata* (Bernstein)
= *Strobilonympha pisciformis* De Mello & Montero
= *S. serpentiformis* De Mello & Montero
= *S. schizophyla* De Mello & Montero
- Family : CALONYMPHIDAE Grassi
- Genus : *Stephanonympha* Janicki
19. *S. minuta* Das & Choudhury
 20. *S. perronciti* (De Mello & De Brito)
= *Metastephanonympha perronciti* De Mello & De Brito
 21. *S. pyriformis* Das & Choudhury
 22. *S. reenstiernai* De Mello
 23. *S. silvestrii* Janicki
= *S. silvestrii havilandi* Grassi
- Family : TRICHOMONADIDAE Chalmers & Pekkola
- Genus : *Trichomonas* Donne
24. *T. costulata* De Mello
- Genus : *Trichomitopsis* Kofoed & Swezy
25. *T. termitis* (Imms)
= *Trichomonas termitis* Imms
= *Ditrichomonas termitis* Cutler
- Order : HYPERMASTIGIDA
- Family : HOLOMASTIGOTIDAE Janicki
- Genus : *Holomastigotoides* Grassi & Foa
26. *H. bengalensis* Chakravarty & Banerjee
 27. *H. campanula* (De Mello)
= *Leidya campanula* De Mello
 28. *H. cingulatum* var *coimbatorensis* De Mello & De Mello
 29. *H. dharwarensis* Karandikar & Vittal
 30. *H. elongata* Uttangi
 31. *H. emersoni* Das
 32. *H. gigas* De Mello
 33. *H. globosus* De Mello
 - 33a. *H. globosus britoi* De Mello
 34. *H. grassii* (De Mello)
= *Pyrsonympha grassii* De Mello
 35. *H. hemigyllum* Grassi
= *Leidya kempi* De Mello
= *L. annandalei* De Mello
= *H. hartmanni* var *indica* De Mello
 36. *H. hollandi* Das
 37. *H. inexpectatus* De Mello

TABLE 1. *Contd.*

38. *H. koidzumii* De Mello
 39. *H. magnus* Uttangi
 40. *H. melloi* Uttangi
 41. *H. mirabile* Grassi
 =*H. hartmanni* Koidzumi
 41a. *H. mirabile katiawarensis* De Mello
 41b. *H. mirabile margabhandui* De Mello & De Mello
 42. *H. ogivalis* De Mello
 43. *H. operculatum* De Mello
 44. *H. ovalis* Uttangi
 45. *H. piriformis* De Mello
 46. *H. proboscifer* De Mello & De Mello
 47. *H. rayi* Karandikar & Vittal
 48. *H. reniformis* De Mello
 49. *H. saccusiformis* Uttangi
 50. *H. sphaeroidalis* De Mello
 51. *H. turboformis* Uttangi
 52. *H. visnagarensis* Uttangi
- Family : SPIROTRICHONYMPHIDAE Grassi
 Genus : Spirotrichonympha Grassi
 53. *S. bhadreshwarensis* Tiwari
 54. *S. coimbatorensis* De Mello
 55. *S. elongata* Grassi
 56. *S. flagellata* (Grassi)
 =*Pyrsonympha flagellata* Grassi
 =*Leidya metchnikovi* De Mello
 57. *S. froilanoi* Karandikar & Vittal
 58. *S. karnataki* Karandikar & Vittal
 59. *S. leidy* Koidzumi
 =*S. leidy* var *leucotermes indicola* De Mello
 59a. *S. leidy damanensis* De Mello
 60. *S. mirabilis* Grassi
 60a. *S. mirabilis indica* De Mello
 61. *S. ovoidea* De Mello
 62. *S. pyriformis* Chakravarty & Banerjee
 63. *S. roonwali* Das
 64. *S. rotunda* De Mello
- Genus : Microjoenia Grassi
 =*Torquenympha* Brown
 65. *M. axostylis* Cutler
- Family : JOENIIDAE Janicki
 Genus : Joenopsis Cutler
 66. *J. polytricha* Cutler
- Genus : Parajoenopsis Salcem
 67. *P. cephalotricha* (Cutler)
 =*Joenopsis cephalotricha* Cutler
- Family : EUCONYMPHIDAE Cleveland, Hall, Sanders & Collier

TABLE 1. *Concluded*

Genus	: <i>Pseudotriconympha</i> Grassi & Foa
68.	<i>P. belari</i> De Mello
69.	<i>P. cardiformis</i> Karandikar & Vittal
70.	<i>P. hertwigi simplex</i> De Mello
71.	<i>P. indica</i> Chakravarty & Banerjee
72.	<i>P. pisciformis</i> Karandikar & Vittal
73.	<i>P. ramani</i> De Mello
73a.	<i>P. ramani seminuda</i> De Mello
74.	<i>P. subapicalis</i> Karandikar & Vittal
Family	: TRICHONYMPHIDAE Kent
Genus	: <i>Protrichonympha</i> Saleem
75.	<i>P. pristina</i> (Imms)
	= <i>Trichonympha pristina</i> Imms
	= <i>Pseudotriconympha pristina</i> (Imms) Cutler
Genus	: <i>Trichonympha</i> Leidy
76.	<i>T. fletcheri</i> De Mello
77.	<i>T. gujarathensis</i> Uttangi
78.	<i>T. turkestanica</i> Bernstein

DISCUSSION

It is now a well established fact that in the gut of lower termites (i.e. termites of the families Mastotermitidae, Kalotermitidae, Hodotermitidae and Rhinotermitidae) presence of flagellates is obligatory. These flagellates help in digesting wood particles (cellulose) for their termite hosts which in turn offer them shelter in complete anaerobic condition inside the gut and ensure their food-supply. In the context of this true mutualism between the flagellates and the termites, Zoologists interested in this field tried to find out whether there is any strict host-specificity of the flagellates particularly in view of the fact that "they have been living in an extremely sheltered intestinal environment for an estimated 200 million years or more without the necessity of search for food or to avoid predators" (Emerson 1971).

Results achieved so far in this regard indicate that host specificity of these flagellates is not rigid. Rather when more and more termites will be examined for their symbiotes, the flexibility of host-specificity of these protozoa may be more and more exposed. Nevertheless, the distribution of all of these protozoa is not random. Some of these flagellates are found to be restricted to some particular groups of termites only. Oxymonadidae, Devescovichidae and Calonymphidae, for example, are found almost exclusively in the gut of Kalotermitidae.

The genus *Pyrsonympha* Leidy is known to occur in *Reticulitermes* only whereas genus *Streblomastix* Kofoid and Swezy is restricted to the gut of *Zootermopsis*.

205 species of lower termites have been studied so far all over the world with the record of 391 species and sub-species of flagellates (Yamin 1979). The data available thereby indicate that the distribution of these flagellate symbiotes is primarily related with the systematic relationship of their hosts rather than with host's zoogeographical or extra-ecological associations. Moreover detailed study of Kirby (1947) has revealed that faunules of a particular termite species are generally identical irrespective of its distribution. Absence of certain species of flagellates from all the members of a termite colony is due to occasional absence of this symbiote from the parental pair which started the colony. All these are in corollary with the findings that all the species of flagellate symbiotes are carried through the molt which results in the winged imago and are thus transmitted from colony to colony through alates.

In light of this, if works on the flagellate symbiotes from Indian termites are analysed few discrepancies are clearly noticed. Firstly, from the gut of *Coptotermes heimi* (Wasmann) and *Heterotermes indicola* (Wasmann) 27 species and 25 species of flagellates have been reported respectively (Table 2). This seems to be very unusual compare to the data available on this group from the other parts of the globe (*op. cit.* Yamin).

TABLE 2. List of flagellate symbiotes recorded from Indian *Coptotermes heimi* (Wasmann) and *Heterotermes indicola* (Wasmann)

Name of the host	Name of flagellate symbiotes
1. <i>Coptotermes heimi</i> (Wasmann)	1. <i>Tricercomitus divergens</i> Kirby
	2. <i>Devescovina cometoides</i> De Mello
	3. <i>D. lemniscata</i> Kirby
	4. <i>Foaina nana</i> (Kirby)
	5. <i>Stephanonympha perronciti</i> (De Mello & De Brito)
	6. <i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
	7. <i>H. campanula</i> (De Mello)
	8. <i>H. dharwarensis</i> Karandikar & Vittal
	9. <i>H. elongata</i> Uttangi
	10. <i>H. emersoni</i> Das

TABLE 2. *Concluded*

Name of the host	Name of flagellate symbiotes
	11. <i>H. hemigymnum</i> Grassi
	12. <i>H. mirabile</i> Grassi
	13. <i>H. mirabile katiawarensis</i> De Mello
	14. <i>H. ogivalis</i> De Mello
	15. <i>H. rayi</i> Karandikar & Vittal
	16. <i>H. sphaeroidalis</i> De Mello
	17. <i>H. turboformis</i> Uttangi
	18. <i>Spirotrichonympha bhadreshwarensis</i> Tiwari
	19. <i>S. elongata</i> Grassi
	20. <i>S. flagellata</i> (Grassi)
	21. <i>S. froilanoi</i> Karandikar & Vittal
	22. <i>S. karnataki</i> Karandikar & Vittal
	23. <i>S. roonwali</i> Das
	24. <i>Pseudotrichonympha cardiformis</i> Karandikar & Vittal
	25. <i>P. indica</i> Chakravarty & Banerjee
	26. <i>P. pisciformis</i> Karandikar & Vittal
	27. <i>P. subapicalis</i> Karandikar & Vittal
2. <i>Heterotermes indicola</i> (Wasmann)	1. <i>Holomastigotoides bengalensis</i> Chakravarty & Banerjee
	2. <i>H. campanula</i> (De Mello)
	3. <i>H. gigas</i> De Mello
	4. <i>H. globosus</i> De Mello
	5. <i>H. grassii</i> (De Mello)
	6. <i>H. hemigymnum</i> Grassi
	7. <i>H. hollandei</i> Das
	8. <i>H. koidzumii</i> De Mello
	9. <i>H. magnus</i> Uttangi
	10. <i>H. melloi</i> Uttangi
	11. <i>H. mirabile katiawarensis</i> De Mello
	12. <i>H. ogivalis</i> De Mello
	13. <i>H. ovalis</i> Uttangi
	14. <i>H. sphaeroidalis</i> De Mello
	15. <i>H. saccusiformis</i> Uttangi
	16. <i>H. visnagarensis</i> Uttangi
	17. <i>Spirotrichonympha flagellata</i> Grassi
	18. <i>S. leidy</i> Koidzumi
	19. <i>S. leidy damansensis</i> De Mello
	20. <i>S. pyriformis</i> Chakravarty & Banerjee
	21. <i>S. rotunda</i> De Mello
	22. <i>Pseudotrichonympha belari</i> De Mello
	23. <i>P. cardiformis</i> Karandikar & Vittal
	24. <i>P. indica</i> Chakravarty & Banerjee
	25. <i>Trichonympha gujarathensis</i> Uttangi

Secondly, occurrence of devescovinid and calonymphid flagellates (*Devescovina cometoides*, *D. lemniscata*, *Foaina nana* and *Stephanonympha perronciti*) and *Tricercomitus divergens* from the gut of a rhinotermitid termite, *Coptotermes heimi* needs critical consideration. As mentioned earlier, these flagellates are almost exclusively restricted to the kalotermitid termites. The present author during his taxonomic studies of termites of West Bengal and Andaman islands, India has examined gut contents of a large number of *Coptotermes heimi* (more than 1000 exs.) from different localities but could never find any devescovinid and/or calonymphid flagellates. Kirby (1947) is quite justified in his remark "Mello and Brito (1929) in describing *Metastephanonympha* and certain species of *Devescovina* considered that the host is a species of *Coptotermes* but what is known of the protozoa makes it certain that they were incorrect and that it is one of the kalotermes group" In one occasion De Mello (1953) himself confessed that the material he had used for study as *Coptotermes heimi* was wrongly identified.

Thirdly, some works of De Mello, the major contributor of this field from India, have caused a great deal of inconvenience as pointed out by Kirby on several occasions and by Cross (1946), Honigberg (1970) and Emerson (1971). Recently Honigberg (1979) (his personal communication to the present author) has opined "as far as De Mello's contributions are concerned, one could only wish that there were a way to suppress them ; but unfortunately there is none." One of the Uttangi's contribution (1959) in this field has also created confusions. He has recorded one species of *Trichonympha* from the gut of a rhinotermitid termite, *Heterotermes indicola*. So far 15 species of *Trichonympha* (excluding Uttangi's one) are known from the gut of termites. Kirby (1932, 1937, 1949) has made a detailed study in this regard. But excepting the genus *Reticulitermes* which is very distinct as regards its flagellate symbiotes are concerned, no other genus of the family Rhinotermitidae is found to harbour *Trichonympha*. *Heterotermes indicola* has also been widely studied throughout India for many years. But in no other occasion *Trichonympha* has been recorded from this host.

Discrepancies found in the works on flagellate symbiotes from Indian termites are mainly due to :—

1. Wrong identification of the termite hosts ;
2. Wrong identification and inadequate description of flagellate symbiotes and

3. Lack of proper understanding regarding organelles of different groups of flagellates.

The last one will be clearly understood if any Protozoologist carefully reads the description of De Mello and Montero's genus *Strobilonympha* in which the authors have very nicely blended the characteristic features of hypermastigote and polymastigote flagellates.

Thus, all the confusions regarding the taxonomic status of flagellate symbiotes or their record from termite hosts in India are mainly rested on De Mello's work on the three termite hosts—*Cryptotermes havilandi*, *Coptotermes heimi* and *Heterotermes indicola* and Uttangi's works on the latter two hosts. As the types of the concerned flagellate species are not available so it is proposed to undertake a detailed study of flagellates of the said three termite species from Goa, Daman and Dharwar (the type locality of De Mello's and Uttangi's species) and to prepare a fresh list of flagellates from their gut. This in addition to the data on this group available from other parts of India would certainly help in clearing up major confusions regarding the proper identity of flagellate symbiotes with reference to their host-species.

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FACTORS INFLUENCING CERCARIAL LIBERATION FROM THEIR SNAIL-HOSTS

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INTRODUCTION

Authors are unanimous that the liberation of cercariae from the snail-hosts depends on a number of factors like light (Rees, 1931 ; Faust and Hoffman, 1934 ; Bolwing, 1955 ; Smith, 1966), temperature (Cort, 1922 ; Rees, 1931 ; Isobe, 1923 ; Kuntz, 1947), pH of water (Atkins and Lebour, 1924 ; Bauman *et al.*, 1948 ; Verma, 1961) and starvation (Brackett, 1940 ; Bauman *et al.*, 1948 ; Sinderman *et al.*, 1957). However, most of the workers paid special attention to a particular factor but for the clear understanding a consideration of all the factors is essential. The present communication which deals with the factors influencing the cercarial liberation from the snail-hosts *Lymnaea acuminata* and *Indoplanorbis exustus*, is one such attempt.

MATERIAL AND METHODS

The snails *Lymnaea acuminata* and *Indoplanorbis exustus* of different size groups were collected from a tank near Joramandir, Beliaghata, Calcutta by the end of each month during the period November, 1977 to October 1979. The snails were maintained separately to note the liberation of cercariae. To study the influence of light on the liberation of cercariae a table lamp with 100w. bulb was taken and placed over the test tubes containing infected snails. The snails were exposed to light for a period of 12 hours and also for 24 hours as per experimental programme. The number (mean) of cercariae liberated from the snail hosts was calculated from three parasitized snails daily, for a period of five days. To correlate the rate of cercarial liberation in different seasons data on temperature and pH of water were recorded in each occasion.

The snails of both the species were measured and categorised into 6 different size groups to ascertain the rate of infection in relation to the size groups of the snail species concerned.

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It is said that starvation plays an important role in the liberation of cercariae. To study this same the infected snails were allowed to live without food and observations were made on the rate of cercarial liberation with the progress of starvation.

OBSERVATIONS

A total of 1369 and 1406 *L. acuminata* were collected in two years, 1977-78 and 1978-79 respectively. Of the 1369 snails 481 (35.13%) and 424 (30.15%) out of 1406 snails were found infected with *Schistosoma nasale* Rao, 1933. Data collected in different months of the year suggest that there exists a strong seasonal effect on the rate of cercarial infection. The rate of infection was minimum (25 to 30%) during prewinter months (October-December) while peak was observed in monsoon in both the years (Fig. 1). In course of two years period

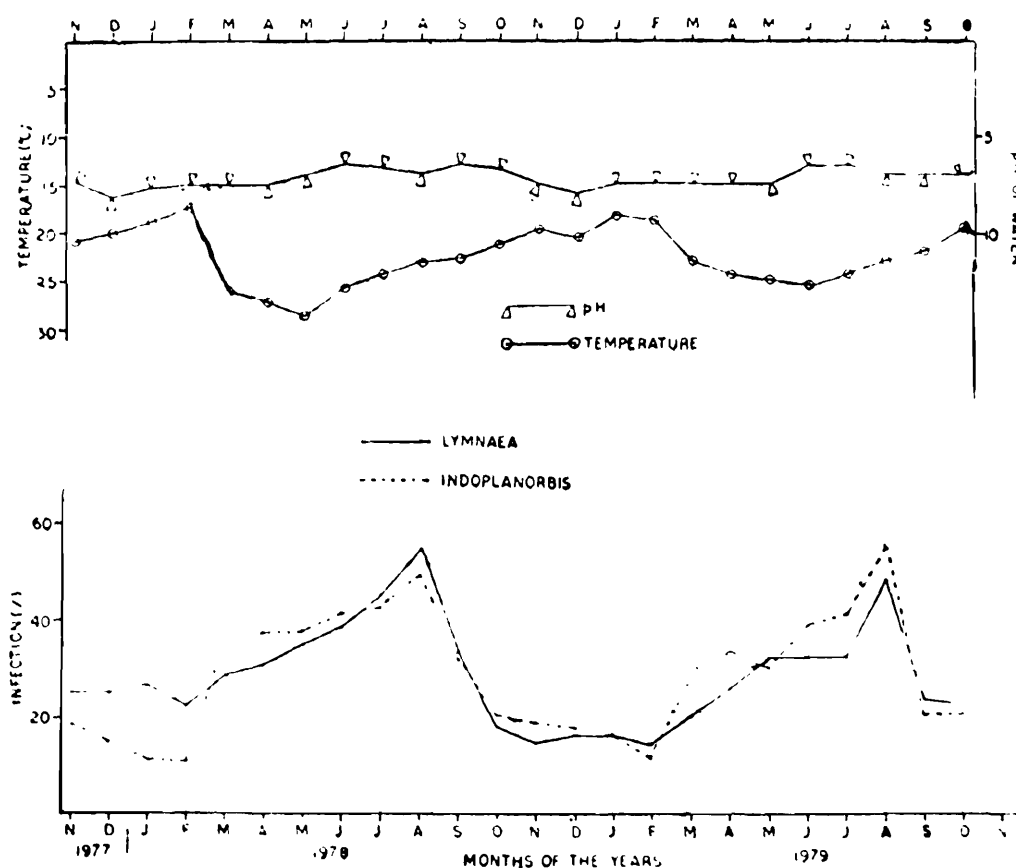


Fig. 1. Seasonal variations in the rate of cercarial liberation in *L. acuminata* and *I. exustus* in relation to pH and temperature of the tank water.

a total of 2027 *I. exustus* were examined and 691 (34.08%) were found infected with *Cercariae indicae* XVII Sewell 1923. The rate of infection was almost similar in both the years. The peak was observed in monsoon and minimum rate of infection was observed in prewinter

period (Fig. 1). The data on temperature and pH of water as recorded during each sampling have been plotted against the percentage of infection in each month (Fig. 1). It is observed that during prewinter the mean temperature range was between 20 to 26°C while in monsoon it was little higher, 22°C to 30°C. The pH value during peak period of infection was 7.0 while in prewinter it was 7.5.

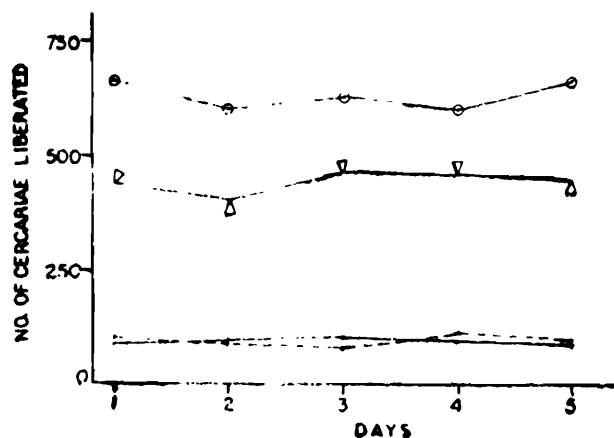


Fig. 2. Rate of cercarial liberation from the infected *L. acuminata* exposed to different conditions.

L. acuminata exposed to light in day hours liberated 409 to 458, on an average 444.8 cercariae per day while the same snails liberated only 84 to 114, on an average 99.4 cercariae per day in 12 hours dark period i.e., in night (Fig. 2). The infected snails exposed to light for a period of 24 hours liberated 600 to 668, on an average 633.6 cercariae daily (Fig. 2). But when the snails were kept under darkness for 24 hours consecutively for a period of five days liberated 93 to 108, average 99.4

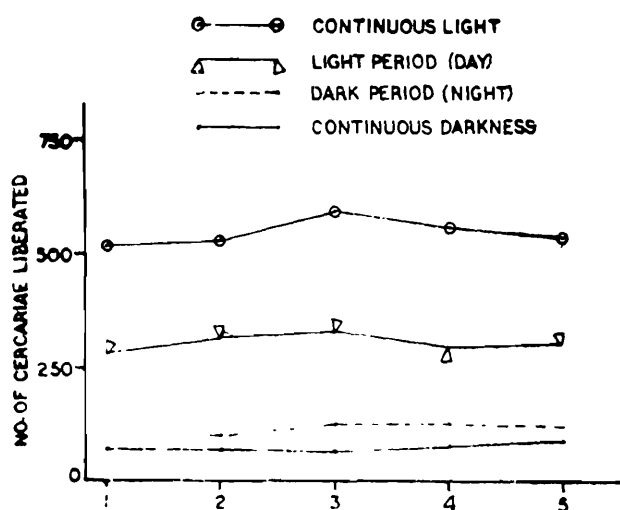


Fig. 3. Rate of cercarial liberation from the infected *I. exustus* exposed to different conditions.

cercariae per day (Fig. 2). Infected *I. exustus* when exposed to 12 hours light and 12 hours dark period liberated cercariae 286 to 330, on an average 307.6 per day and between 65 to 83, on an average 74.6 per day respectively (Fig. 3). Continuous exposure to light for a period of five days reveals that the number of cercariae liberated was seven times higher than those kept in darkness for the same length (Fig. 3).

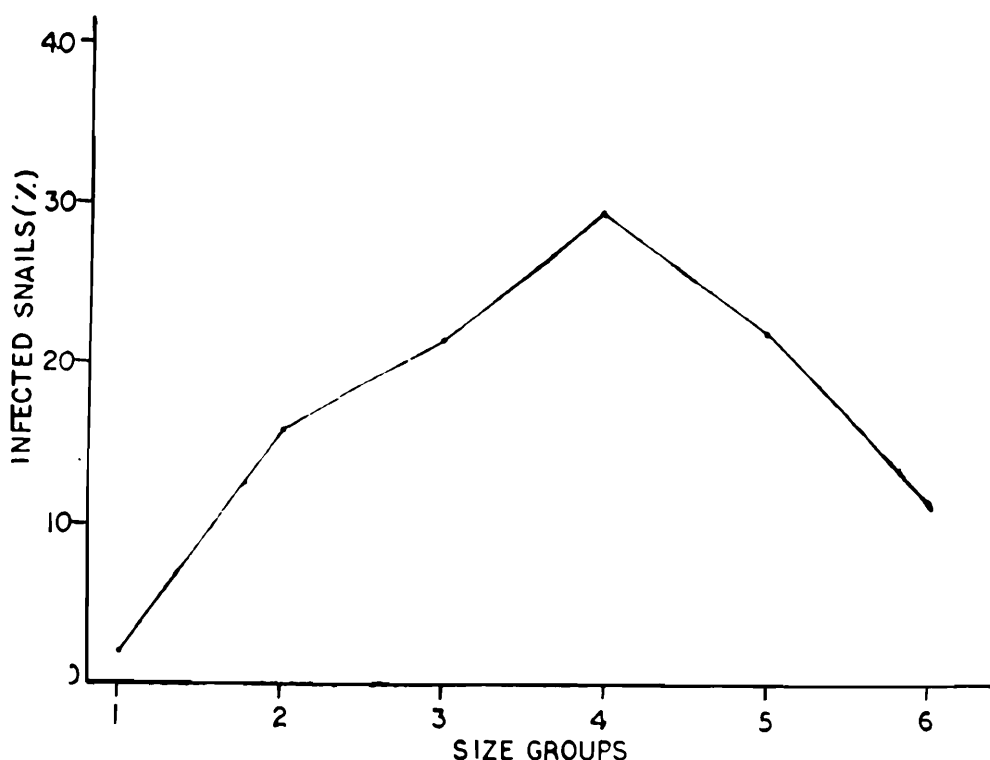


Fig. 4. Percentage of cercarial infection in different size groups of *L. acuminata* (1=8 mm and below, 2=8.1 mm to 12 mm, 3=12.1 mm to 16 mm, 4=16.1 mm to 20 mm, 5=20.1 mm to 24 mm, 6=24.1 mm and above).

Studies on the cercarial liberation from different size groups of the host-snails of both the species indicate that the snails of lower size groups are less susceptible to attack while with the increase in age of the snails the infection rate is observed higher (Figs. 4 and 5). Snails between 20.1 mm to 24 mm and 10.1 mm to 12 mm size groups of *L. acuminata* and *I. exustus* showed maximum infection rate, i.e. 33.7% and 29.23% respectively. Surprisingly infection rate is very low in the snails of older size groups.

Experiments on the liberation of cercariae from the starved but infected snails of both the species showed that the rate of liberation was higher in the first day. But with the progress of starvation the rate of cercarial liberation declined gradually and at the end of 7th week no cercaria was found to be liberated,

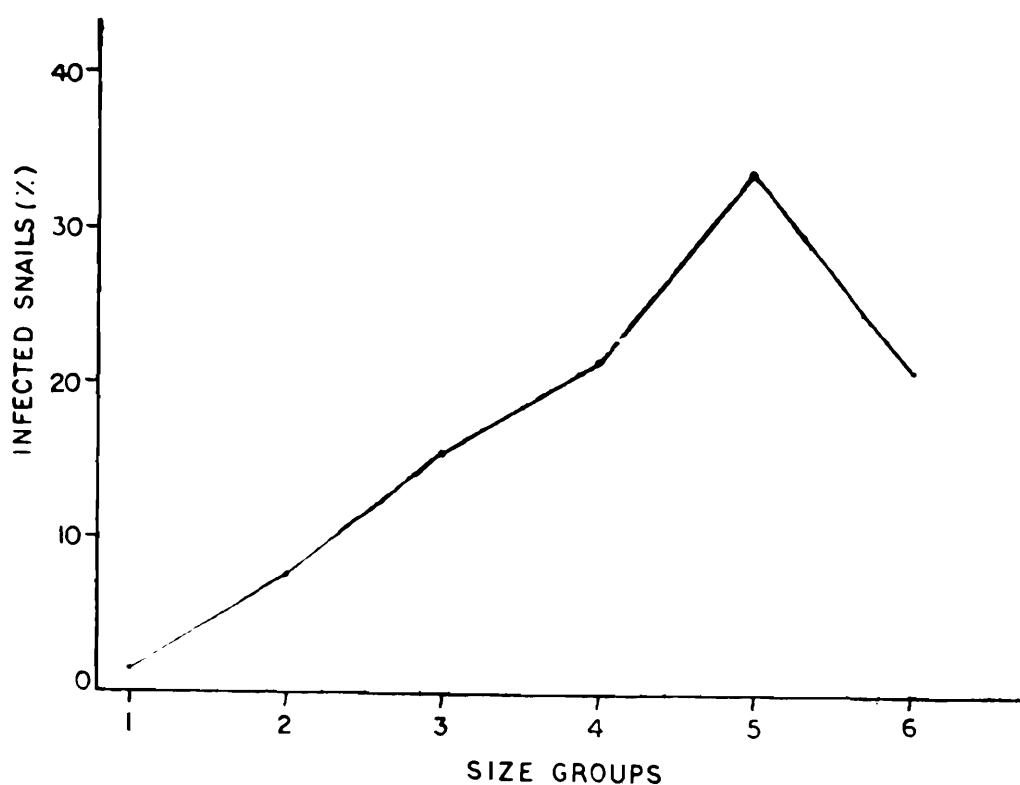


Fig. 5. Percentage of cercarial infection in different size groups of *I. exustus* (1= 6 mm and below, 2=6. 1 mm to 8 mm, 3=8. 1 mm to 10 mm, 4=10. 1 mm to 12 mm, 5=12. 1 mm to 14 mm, 6=14. 1 mm and above).

TABLE 1. A comparative account of the rate of cercarial liberation with the progress of starvation in *Lymnaea acuminata* and *Indoplanorbis exustus*.

Length of starvation (days)	No. of individuals taken		No. of cercaria liberated		No. of cercaria liberated per snail	
	<i>L. acuminata</i>	<i>I. exustus</i>	<i>L. acuminata</i>	<i>I. exustus</i>	<i>L. acuminata</i>	<i>I. exustus</i>
1	60	60	25320	27960	422	466
8	52	50	18980	19000	365	380
15	46	40	15226	14400	331	360
22	41	29	11521	7772	281	268
29	34	17	4930	1853	145	109
36	26	9	1820	99	70	11
43	14	3	378	—	27	—
50	7	—	—	—	—	—

DISCUSSION

Studies on the seasonal fluctuations in the liberation of cercariae from the snail-hosts have been made by a number of workers. It is reported that there is only one peak of infection in a year in *Indoplanorbis lapedarea* (Ameel, 1934 ; Sogandares-Barnel, 1965), *Bulinus* spp. (Archibald, 1933 ; Moore *et al.*, 1953), *Indoplanorbis* (Srivastava and Dutta, 1962), and in a number of vector snail species (Pandey and Agarwal, 1978). However, Sewell (1922), Miller and Northup (1926), Rees (1931), Rankin (1939), Ollerenshaw (1964), Probert (1966), and Mukherjee (1966) reported two peaks of cercarial infection. The present observation indicate that there is only one peak and that is confined to monsoon. It is probable that the infection rate is dependent on the density of host population and their activity as both *L. acuminata* and *I. exustus* were available maximum during monsoon.

There are several physicochemical factors that control the host environment which regulates the rate of cercarial liberation. Of the factors, temperature plays an important role in the liberation of cercariae has been reported by Cort (1922), Rees (1931, 1948), Archibald and Marshall (1932), Kendall and Mc Cullough (1951) and Verma (1961) in different species of lymnaeids and planorbids. It is probable that the variation in the rate of cercarial liberation is related with the fluctuations of temperature which affects the physiological conditions of the host tissues. Another point is that due to the physiological changes in the host tissues the production of cercaria may be inhibited and the rate of liberation, obviously, would be low as is evidenced from the present observations on *Lymnea* and *Indoplanorbis*.

Hydrogen-ion concentration of water is a frustrating factor in the release of cercaria. It is still not clear whether due to change in ionic concentration of water the cercariae themselves stop their emergence or it is due to the change in host-environment which inhibits cercarial liberation.

Investigators are in opinion that fluctuation in the rate of cercarial liberation at different times of a day is primarily dependent on the intensity of light (Rees, 1931 ; Nasir, 1960 ; Thapar and Tandon, 1952 ; Ullman, 1954 ; Smith, 1966). It seems that there exists rhythmicity in the liberation of cercariae within a period of 24 hours. In majority of cases the cercarial liberation is high in day time, about 6 to 7 fold than that in the night. It appears that the rhythmicity is controlled by the presence or absence of light.

Studies on the effect of starvation of the host-snail on the liberation of cercariae are rather scanty. It is reported that the liberation of *Schistosoma* cercariae is resumed in snails fed after starvation (Brackett, 1940 ; Bauman *et al.*, 1948). According to Kendall (1949), liberation of *Fasciola hepatica* from starved *Lymnaea truncatula* reduces one-sixth of that in well fed snails by 5 to 6 weeks. As the cercariae develop mostly in the digestive glands of the host-snail it is probable that the development and nourishment of the cercariae are dependent on the amount of stored glycogen as suggested by Dasgupta (1972). And when there would be very little or no glycogen in the digestive gland, the host would become free from the cercariae.

From the foregoing discussion it is clear that there are number of factors influencing the liberation of cercariae but how they act on the hosts or parasites is still a question. Secondly, whether hosts try to get rid of from their parasites or the parasites try to come out of the host or it is a complex phenomenon of joint responsibility is not known.

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LYMNAEA—A VECTOR OF DIGENETIC TREMATODES OF WEST BENGAL

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INTRODUCTION

Gastropod molluscs are the common intermediate hosts of various types of digenetic trematodes. Present authors have chosen *Lymnaea* spp., the freshwater pulmonates, as they are available in abundance in all over the state of West Bengal and are the supposed vectors of a large number of trematode parasites. Infection to snail hosts results from the penetration of freeswimming miracidia and after a sequence of intramolluscan phases the cercariae emerge out finally as freeswimming forms. Informations on cercariae are considered important because they serve as a clue to the existence of the digenetic fauna of a region. Very little work on this aspect has been done in the state of West Bengal. Soparkar (1921) initiated the work on cercariae in India. It was Sewell (1922) who made an exhaustive study on different cercariae available from freshwater snails in West Bengal and from 4 other states. Since then DasGupta (1973), and Mukherjee & Ghose (1976, 1977) made some observations on the cercarial fauna of this state. Observation made by the present authors would help much in organising control measures against the spread of trematode infections among the domestic animals, livestock and man as well.

MATERIALS AND METHODS

During the survey period (1978-79) two *Lymnaea* spp. along with other freshwater gastropods were collected at random from their natural habitats of various localities in the eleven districts of Bengal. The snails were collected twice in every month irrespective of their size and age. The snails were brought to the laboratory alive along with pond water and aquatic weeds. The snails were placed individually in separate specimen tubes which they were filled with 15 ml of ordinary tap water. The mouth of the tubes were covered with cotton wool to prevent the escape of *Lymnaea* spp. The snails were exposed to

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diffused sunlight. After a couple of hours the water of the tube was examined carefully under microscope for the presence or absence of cercariae. Those snails which shed cercariae were isolated, others were dissected out to confirm the absence of infection at the end of 4th week. Relevant data were noted down and their infections with different cercariae were recorded.

Study areas : West Bengal, one of the eastern states of India, covers an area of 87853 square kilometers and is divided into 16 districts. Of these 16 districts collections were made from the districts of Bankura, Birbhum, Burdwan, Calcutta, Howrah, Hooghly, Midnapur, Murshidabad, Nadia, Purulia and 24-Parganas. Sanils were collected from ponds, tanks, paddy-fields, canals and rivers, etc.

RESULTS AND DISCUSSIONS

Two species of *Lymnaea* were examined in addition to different species of freshwater gastropods. They were *Lymnaea acuminata* f. *rufescens* (Gray) and *Lymnaea luteola* f. *ovalis* (Gray). Out of a total of 14487 collected 3702 were *L. acuminata* and 10785 were *L. luteola*. The number of infected *L. acuminata* and *L. luteola* were 861 and 507 respectively. The percentage of infection with various types of larval parasites (cercariae) in the two species were 23.26 and 4.7 respectively. Of the infected *L. acuminata* the percentage of infection with different types of cercariae were as follows—echinostome cercariae 87.8, furco-cercous cercariae 10.1, xiphidiocercariae 1.39 and amphistome cercariae 0.69 where as in case of *L. luteola* the percentages were 52.66, 7.7, 2.36 and 37.28 respectively (Table 1). Frequency of snail species infected with larval trematodes varied with the total population. This has

TABLE 1.

Species of snails	No. of snail collected.	No. & % of infection.	Types of cercariae and % of infected snails.			
			Echinos- tome	Furco- cercous	Xiphidio- cercous	Amphis- tome
1. <i>Lymnaea acuminata</i> f. <i>rufescens</i>	3702	861 (23.26)	87.8	10.1	1.39	0.69
2. <i>Lymnaea luteola</i> f. <i>ovalis</i>	10785	507 (4.7)	52.66	7.7	2.36	37.28

been observed that the population of snail species and the frequency of infection varies from place to place and also with the seasons. Sewell (1922), Rao (1932), Singh (1959), Mukherjee (1966), Sahai (1969-70), Erasmus (1972), Dasgupta (1973), Mohandas (1974), Muraleedharan *et al.* (1977) and others reported similar types of observations. Fluctuation of infection rate may be due to wide range of ecological factors. Present study also revealed that the incidence of infection in snails with larval trematodes is higher in ponds than in any other habitat.

High incidence of cercarial infection was observed in *Lymnaea* spp. Similar findings were reported by Rao (1932) from Madras. This situation, perhaps, is due to the wide-spread distribution of the snail host. It is possible that the Lymneidae family may be phylogenetically very primitive and well adapted to withstand the impact of infection. Most common infection in *Lymnaea* spp. was found to be with echinostome cercariae. This observation is in conformity with the findings of Peter (1954) in Madras. It is not known why the *Lymnaea* spp. are largely favoured by the cercarial parasites but it is obvious that the tissue of the snail host may provide a suitable internal environment for the development of larval trematodes in addition to other ecological factors.

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STUDIES ON THE IMPACT ON THE ERYTHROCYTIC ENVIRONMENT OF THE INTRACELLULAR BLOOD PARASITES OF BIRDS

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INTRODUCTION

Haematozoa, at some stage in their development, observed, in the preparation of the blood smears of birds include the genera *Leucocytozoon*, *Haemoproteus*, *Plasmodium*, *Lankesterella*, *Babesia* and *Trypanosoma* belonging to the phylum Protozoa and some microfilariae or the larval nematodes of the phylum Aschelminthes. The trypanosomes and microfilariae are extracellular plasma parasites, and the rest of the haematozoans are intracellular parasites inhabiting the blood cells *i.e.*, either erythrocytes or leucocytes, or both. The present paper, however, deals with the haemosporins viz., *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, to discuss the coactions of some of the representatives which happen to possess in common the same relatively restricted ecological niche *i.e.*, the erythrocytic environment of the avian hosts.

MATERIALS AND METHODS

Both normal and parasitized erythrocytes of avian hosts naturally infected with macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium* were measured as described by Nandi (1978) and Bennett and Campbell (1972, 1975).

The host cell-parasite relationships have been evaluated on the basis of morphometric measurements of macrogametocyte-infected red cells in comparison to normal erythrocytes. For parasites, parasitized erythrocytes and normal erythrocytes, 100 measurements of length, width and area of each category were taken into consideration. The morphometric measurements and indices involved were analysed. Five species of *Leucocytozoon*, 5 species of *Haemoproteus* and 3 species of *Plasmodium* have been incorporated in this study. Indices were

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calculated as follows : (1) Parasite index (PI) = Mean area of macrogametocyte/mean area of uninfected erythrocyte. (2) Host cell-parasite index (HCPI) = Mean area of host cell-parasite complex/mean area of uninfected erythrocyte. (3) Host cell nuclear index (HCNI) = Mean area of host cell nucleus/mean area of uninfected erythrocyte nucleus.

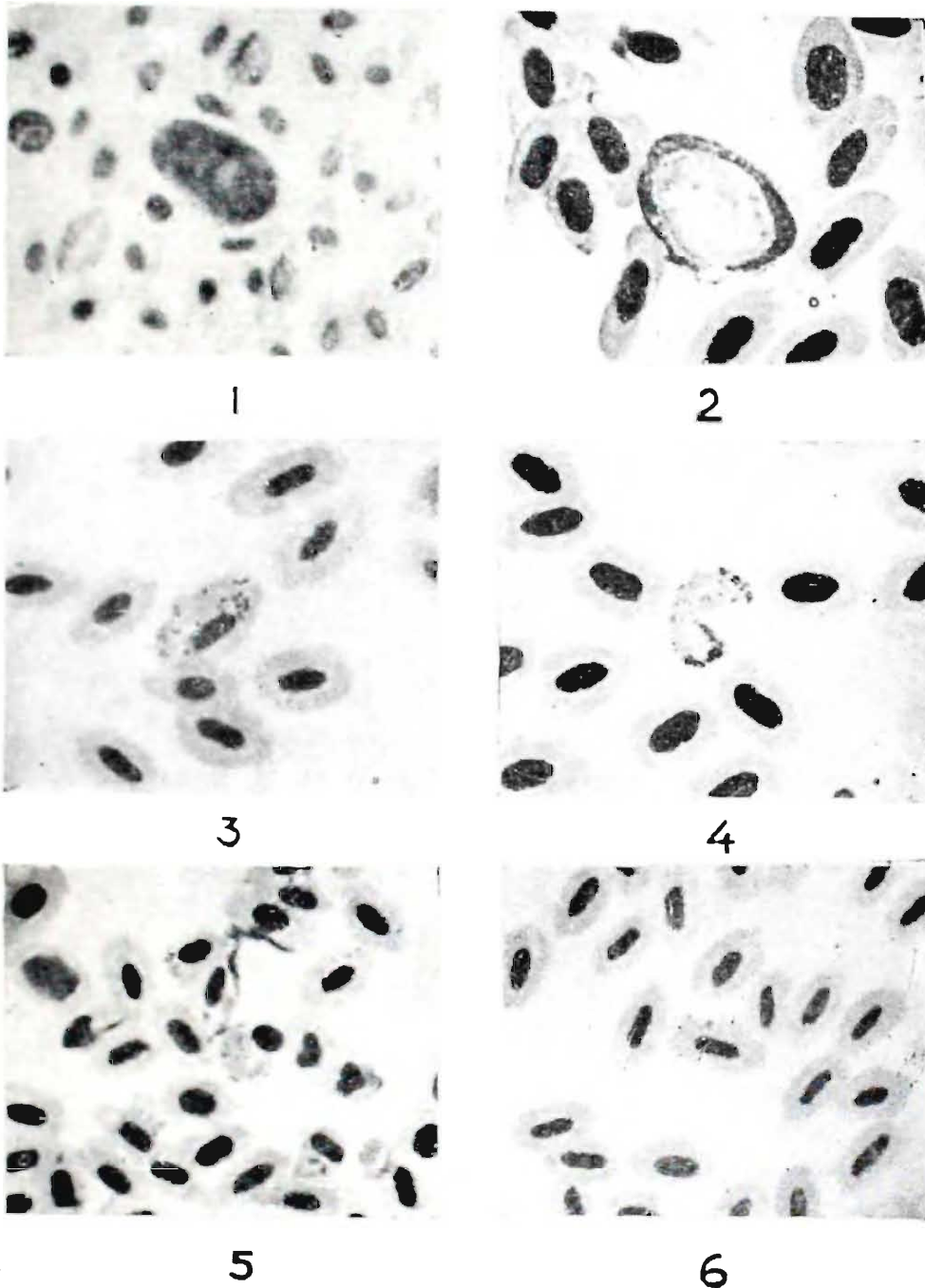
OBSERVATIONS

Avian erythrocytes are nucleated, typically elliptical cells. The erythrocyte nucleus is also elliptical in configuration. The red cell, in an average, measures $11.9 \mu\text{m}$ (0.9) by $6.7 \mu\text{m}$ (0.2) and $62.2 \mu\text{m}^2$ (3.7) in area, and cell nucleus averages $5.7 \mu\text{m}$ (0.3) by $2.5 \mu\text{m}$ (0.3) and $9.6 \mu\text{m}^2$ (1.5) in area.

The characteristic morphologies (Plate 1, figs. 1-6) of the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, infected erythrocytes (host cells) and infected erythrocyte nuclei (host cell nuclei) of birds are presented in Table 1 and their morphometric measurements, in Table 2.

TABLE 1. Differential morphological characteristics of the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, infected host cell and host cell nucleus

	<i>Leucocytozoon</i>	<i>Haemoproteus</i>	<i>Plasmodium</i>
Macro-gametocyte	Large, round to elongate-oval, measuring $10.9 \mu\text{m}$ by $9.4 \mu\text{m}$ and $73.2 \mu\text{m}^2$ in area, greater than the normal erythrocyte in area; cytoplasm coarse, vacuolated, staining deep blue and unpigmented.	Broad sausage to slender halteridial, measuring $12.8 \mu\text{m}$ by $3.5 \mu\text{m}$ and $41.0 \mu\text{m}^2$ in area, less than the normal erythrocyte in area; cytoplasm coarsely granular, vacuolated in some, staining blue and pigmented.	Short slender to round-oval, measuring $8.5 \mu\text{m}$ by $3.9 \mu\text{m}$ and $27.0 \mu\text{m}^2$ in area, usually less than half the normal erythrocyte; other characteristics more or less similar to that of <i>Haemoproteus</i> .
Host cell	Grossly hypertrophied in length, width and area; round-oval to fusiform and never able to retain its original shape, usually attains double the normal cell size, greater portion of the cytoplasm usually occupied by the parasite.	Usually slightly hypertrophied in length and in area, may be enucleated in some, tendency to retain its normal shape, only slightly greater than its normal size, more than 50% of the cytoplasm occupied by the parasite.	Hypertrophy / atrophy not very pronounced, occasionally enucleated, usually retain its original shape and remains unchanged in size, about 50% of cytoplasm occupied by the parasite.



- Fig. 1. Macrogametocyte of *Leucocytozoon sabraezesi* in elongated fusiform host cell.
- Fig. 2. Macrogametocyte of *Leucocytozoon majoris* in round host cell in which the host cell nucleus circumscribe more than $2/3$ the parasite's periphery.
- Fig. 3. Halter-shaped macrogametocyte of *Haemoproteus garnhami*.
- Fig. 4. Macrogametocyte of *Haemoproteus oryzivora* in enucleated host cell.
- Fig. 5. Round macrogametocyte of *Plasmodium relictum* in which the host cell nucleus is deflected to one side.
- Fig. 6. Elongate macrogametocyte of *Plasmodium nucleophilum*.

	<i>Leucocytozoon</i>	<i>Haemoproteus</i>	<i>Plasmodium</i>
Host cell nucleus	Greatly hypertrophied and distorted, assumes various shapes, sometime circumscribe 2/3 the parasite's periphery, mostly unable to retain its original shape, usually pushed to one side and mostly more than thrice its normal size.	Usually atrophied in length and area, tendency to retain its normal shape, located centrally or pushed to a centrolateral position, usually less than its normal size.	Usually atrophied in length, hypertrophied in width and unchanged in area, somewhat round to normal in shape, located centrally or variously deflected, size mostly remains the same.

TABLE 2. Morphometric measurements of the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, infected host cell and cell nucleus of birds.

	Length (μm)	Width (μm)	Area (μm^2)	Index
Macrogametocyte :				
<i>Leucocytozoon</i>	10.9	9.4	73.2	1.2*
<i>Haemoproteus</i>	12.8	3.5	41.0	0.64*
<i>Plasmodium</i>	8.5	3.0	27.6	0.45*
Host cell-Parasite Complex :				
<i>Leucocytozoon</i>	13.7	12.6	118.5	1.9**
<i>Haemoproteus</i>	12.7	6.8	64.0	1.08**
<i>Plasmodium</i>	11.6	6.8	60.9	1.0**
Host cell Nucleus :				
<i>Leucocytozoon</i>	16.0	3.2	33.6	3.3***
<i>Haemoproteus</i>	5.5	2.3	8.4	0.89***
<i>Plasmodium</i>	5.3	2.4	9.0	0.98***
Normal Erythrocyte of hosts infected with :				
<i>Leucocytozoon</i>	11.9	6.7	62.3	—
<i>Haemoproteus</i>	11.9	6.8	63.6	—
<i>Plasmodium</i>	11.7	6.7	60.4	—
Normal Erythrocyte Nucleus of hosts infected with :				
<i>Leucocytozoon</i>	5.7	2.4	9.8	—
<i>Haemoproteus</i>	5.7	2.3	9.6	—
<i>Plasmodium</i>	5.5	2.3	9.2	—

* Parasite index = Mean area of gametocyte/mean area of uninfected erythrocyte.

** Host cell-Parasite index = Mean area of host cell-parasite complex/mean area of uninfected erythrocyte.

*** Host cell Nuclear index = Mean area of host cell nucleus/mean area of uninfected erythrocyte.

The mensural data of the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, and the derived indices of host cell-parasite relationships (Fig. 1); comparative measurements of the

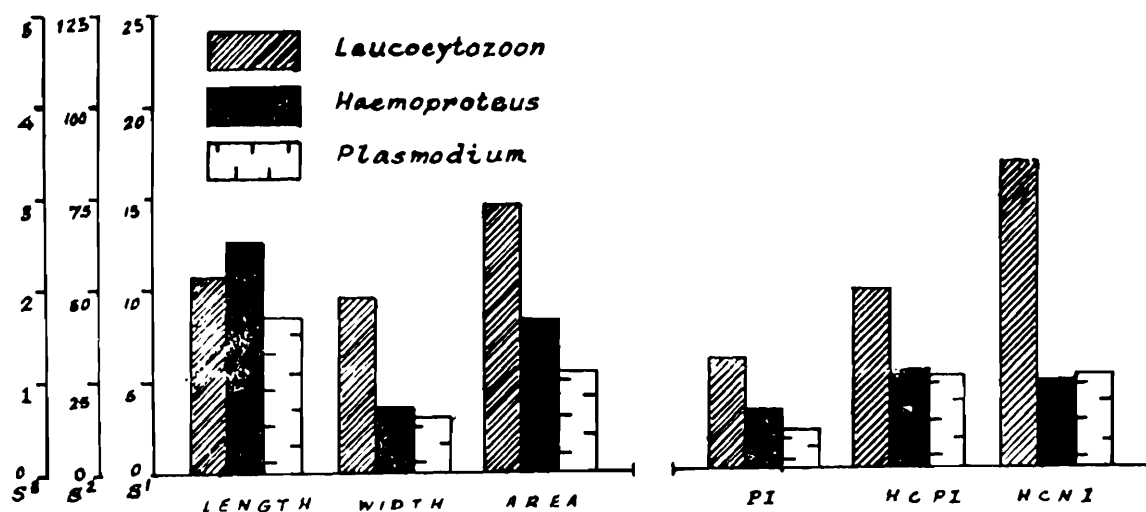


Fig. 1. Comparative morphometric measurements of macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, and their comparative indices. PI=Parasite Index, HCPI=Host cell-parasite index, HCNI=Host cell nuclear index. S₁=Scale for length and width (in μm); S₂=Scale for area (in μm^2); S₃=Scale for indices; Note: Parasite index (PI)=Mean area of gametocyte/mean area of uninfected erythrocyte. Host cell-parasite index (HCPI)=Mean area of host cell-parasite complex/mean area of uninfected erythrocyte. Host cell nuclear index (HCNI)=Mean area of host (infected) cell nucleus/mean area of uninfected erythrocyte nucleus.

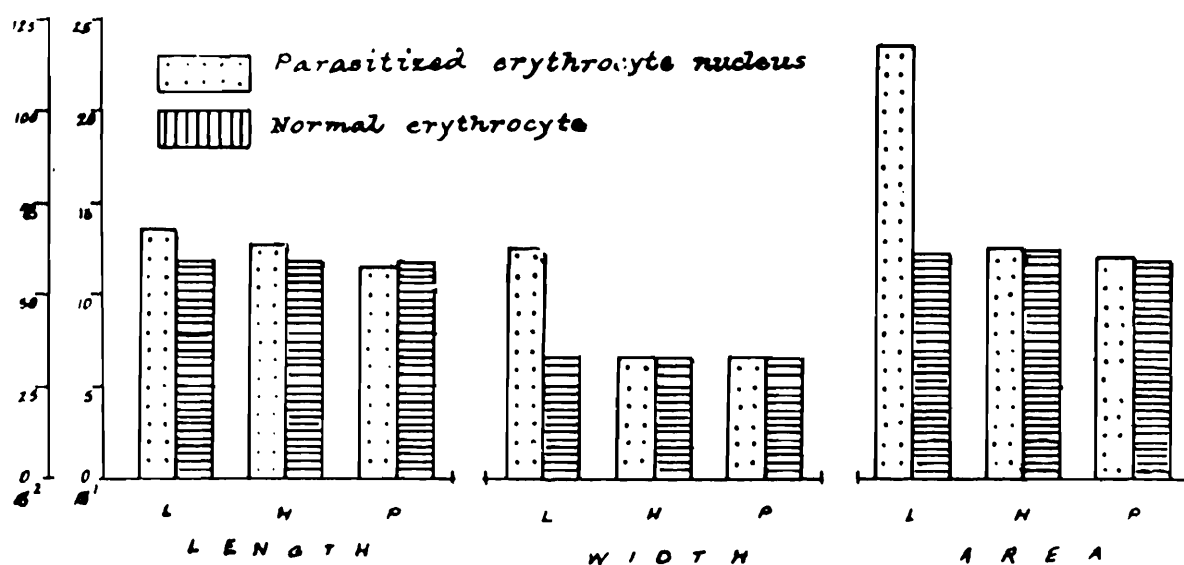


Fig. 2. Comparative mensural data of length (μm), width (μm) and area (μm^2) of *Leucocytozoon* (L), *Haemoproteus* (H) and *Plasmodium* (P) infected erythrocyte and normal erythrocyte. S₁=Scale for length and width (in μm); S₂=Scale for area (in μm^2).

parasitized erythrocytes and the normal erythrocytes (Fig. 2) and that of parasitized erythrocyte nucleus and normal erythrocyte nucleus (Fig. 3) have been represented in the form of histograms. Macrogametocytes of *Leucocytozoon* and their host cell-parasite complex

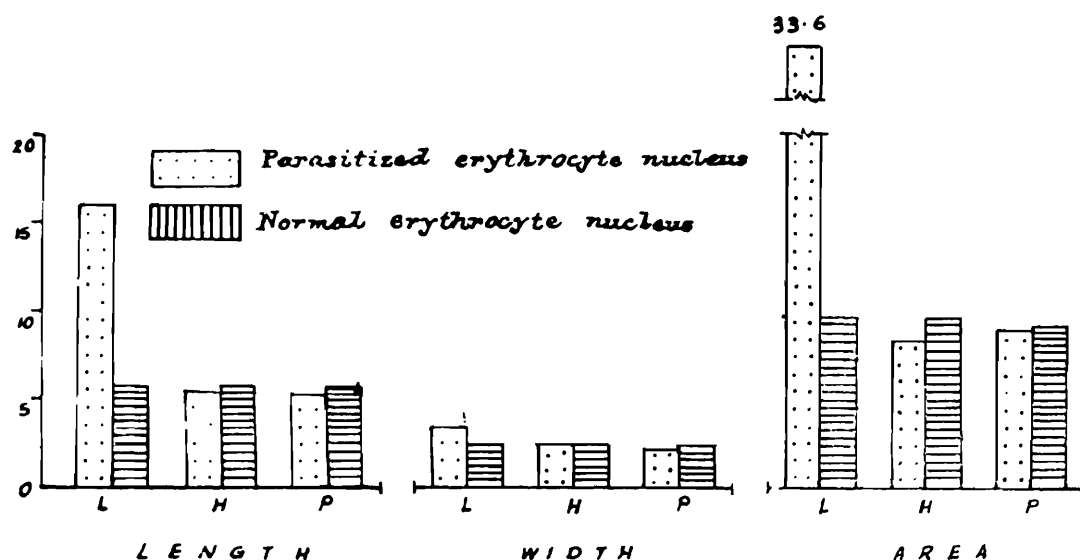


Fig. 3. Comparative mensural data of length (μm), width (μm) and area (μm^2) of *Leucocytozoon* (L), *Haemoproteus* (H) and *Plasmodium* (P) infected erythrocyte nucleus and normal erythrocyte nucleus.

are always greater than those of *Haemoproteus* and *Plasmodium*, and in these regards *Haemoproteus* appears to occupy an intermediate position between *Leucocytozoon* and *Plasmodium*. Furthermore, the area of the host cell nucleus is also larger in case of *Leucocytozoon* than that of *Haemoproteus* and *Plasmodium*—the host cell nucleus is usually atrophied in area in *Haemoproteus* and *Plasmodium* infection (vide Plate II, figs. 1-6).

DISCUSSION

Intracellular blood parasite, as the name implies, does invade blood cells for shelter within and derive nourishments from its host cells. In the process it has to exert its influence on the host cells for its own existence, though the lesser the better. This causes the host cell to change morphologically or at least physiochemically in order to accommodate the parasite, being failed to resist the latter's entry in the threshold of host cell-parasite interaction, and eventually the former reluctantly submit to a nutritional adjustment with the parasite at the biochemical level. Here, the parasites are the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, and the host cells

are the erythrocytes of blood tissue of birds. The discussion, however, is herein restricted to the morphological changes observed both with the parasites and also in the sum total erythrocytic environment.

Assessment of the morphometric measurements of macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, infected host cell and cell nucleus made to evaluate host cell-parasite relationships actively operating in an erythrocytic environment of avian hosts revealed that the host cells, irrespective of the parasite infected, are always hypertrophied. The same is not true with the host cell nucleus—it is usually greatly hypertrophied in *Leucocytozoon* infection and, on the other hand, usually atrophied in *Haemoproteus* and *Plasmodium* infection.

That the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium* assume various shapes, hypertrophies and/or distorts the host cell and cell nucleus in *Leucocytozoon* infection, and host cell hypertrophy along with displacement of the host cell nucleus in *Haemoproteus* and *Plasmodium* infection are on record (Bennett and Campbell, 1975 ; Greiner *et al.* 1977 ; Garnham, 1966). And as the macrogametocytes of *Leucocytozoon* occur in variously modified, greatly distended host cells, the host cells seem unable to exert any influence (or resistance) on the gametocytes' morphology. However, the host cells retain more or less its normal elliptical configuration in *Haemoproteus* and *Plasmodium* infection, even though they are slightly hypertrophied especially in haemoprotoid infection. The host cell and/or the host cell nucleus, on the other hand, appears to influence the shape of the gametocyte of *Haemoproteus* in such a way that it has to bent on itself to become halteridial, encircling the host cell nucleus where the length of the gametocyte is larger than that of the erythrocyte.

The gametocytes of these intracellular parasites, however, exercise a considerable impact on the host cell nucleus by altering its shape or through deflection of the cell nucleus and even by enucleation *i.e.*, pushing the host cell nucleus out of the host cell. The gross hypertrophy and distortion of the host cell nucleus in *Leucocytozoon* infection, sometimes circumscribing 2/3 the parasite's periphery is a clear proof to this contention.

In general, the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium* do morphologically alter the host cell—it is to a greater extent in *Leucocytozoon* infection and to a lesser extent in *Haemoproteus* and *Plasmodium* infection. The host cell-parasite index and the host cell nuclear index in combination with other associated morphological

changes summarized herein would certainly testify the truth of the statement—that damage and derangements done by the parasites would far more excel the resistance and repair mechanisms of the host cells.

SUMMARY

1. Host cell-parasite relationships of intracellular blood parasites viz., *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, have been evaluated morphologically with the help of morphometric measurements of the macrogametocytes and macrogametocyte-infected red cells in relation to normal erythrocytes.
2. Differential morphological parameters of the macrogametocytes of *Leucocytozoon*, *Haemoproteus* and *Plasmodium*, in addition to subsequent changes in the infected host cell and host cell nucleus have been enumerated.
3. The mensural data and derived indices for the same have also been presented.
4. The macrogametocyte-morphologies are specific for the parasites and are occasionally partially influenced by the host cells while the morphological changes of the host cells and host cell nuclei are mostly determined by the parasite, infecting the erythrocytes.

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ENVIRONMENT AND HOST SELECTION BY INSECTS

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It has been stated that "the nature reveals itself very slowly and that the rate at which it reveals depends upon the methods used for its exploration" In this category comes the relationship between plants and insects. Insects and plants have been living together for millions of years (much before the *Homo sapiens* made their appearance on the scene) and they have much to teach about co-evolution in a given environment. This becomes apparent also from the fact that the insects have been adapting themselves to the changing agricultural practices during the last 1000 years or so. In recent years the introduction of high yielding varieties and changed practices have changed the host environment so much that the problems of pests and diseases have been aggravated in some crops, notable amongst them in recent years being the brown plant hopper, *Nilaparvata lugens* and the paddy gall midge, *Pachytiplosis oryzae*, on paddy *Spodoptera litura* on cotton, maize and tobacco, *Atherigona soccata* on sorghum, scab and codling moth on apple, Karnal bunt, "Molya" and *Helminthosporium* on wheat. Further, the insect pests have also been changing their host because of the change in the varieties, a classical example of this would be the *Pyrilla perpusilla* now becoming a pest of sorghum and maize. Indeed, one can analyse the factors responsible for this changed behaviour more accurately now than before.

Gordon (1959) recognized "an unending biochemical contest between metazoans and food organisms". This competition led to an interaction of two independently mutating systems (Dethier, 1970). The mutations are independent, but ecologically the two biochemical systems are interlinked. The insect plant relationship could thus range from a plant predator to plant parasite to symbionts. In the present context we are more interested in the parasitic and predatory relationship of insects with plants because it is this relationship which affects the agriculture most. In this connection it may be worthwhile to mention that a very conservative estimate of the losses in agriculture due to insect pests and diseases is around 15-20%.

The phytophagous insects display a wide range of relationship with plants, varying from polyphagy to extreme monophagy. Table 1 gives the distinguishing features of this relationship. The polyphagy does not recognize any differences in plants, with respect to nutrition

TABLE 1. Distinguishing features of various insects—Host plant relationship.

Type of relationship	Niche	Reproduction
1. Polyphagus	Broad	Host independent
2. Oligophagus	Intermediate	Partially host dependent
3. Monophagus	Narrow	Fully host dependent

or allelochemicals (phagostimulants) with the result that it accepts and flourishes in the very broad niche in a given environment. Similarly its reproduction is host independent and it has an advantage that the population build up is not dependent on the presence of any one particular species of host plant. In contrast to this the extreme monophagy depends upon the presence of a particular plant because it is *this plant* which can satisfy its requirement for allelochemicals, nutrition and successful reproduction. The monophagy entails that the physiology of the insect becomes very much host dependent and that the insect species in turn avoids interspecific competition. Population build up in monophagous insects is host dependent and there is a direct relationship between the population of host plant and insects. Further it also provides for the inter-linking of the biochemistry of the plant to that of the sensory physiology of insects with respect to host selection.

One of the characteristics of insects is that they use chemical signals for transmitting information between individuals. In other words, chemical communication plays a dominant role in insects. They use it not only for recognizing proper hosts but also for successful reproduction. The plants provide not only feed but also rendezvous points for sexual reproduction and oviposition. Aspects of the process by which insects select plants as feeding, mating or oviposition sites have been reviewed by Chapman (1974), Markel (1974) and Schoonhoven (1977).

Recently green leaf components which elicit the general behavioural response in several phytophagous insects for host selection have been elucidated. 3-Hexane-1-ol and 2-hexanal are attractants to *Bombyx mori* (Watanabe, 1958). Trans-2-hexanol is an incitant for the 'calling' behaviour of female *Antheraea* moth (Riddiford, 1967). Adults of vegetable weevil were attracted by 3-hexane-1-ol and both 3-hexane-1-ol and

hexanol attracted the larvae. Hexane-1-ol, cis-3-hexane-1-ol and cis-2-hexane-1-ol are phagostimulatory to *Epilachna* (Murray *et al.* 1972, Visser and Ave, 1978). Host selection in phytophagous insects is a very flexible process which may begin with the acceptance of a plant for feeding and/or oviposition. As the food supply of the insects is not contiguous as a rule, more often than not, the ovipositional behaviour of the insect with respect to its host plant determines the survival of the off-spring. Furthermore, it must be stated that the successful search of a larval host plant by the adults is a pre-requisite for the oviposition of an extremely monophagous insects. This requirement is not so stringent for a truly polyphagous insect. Thus, the female must recognize the proper plant which can sustain the population of its offspring. The secondary volatile chemicals given out by plants play a significant role in this regard.

Plants contain a large number of so-called secondary substances, viz., alkaloids, betains, glycoside, flavenoid etc. Some of these act as phagostimulants or deterrents for insects and thus affect colonization of plants by insects. The importance of phagostimulants in insect/host plant relationship has been recognized (Thorsteinson, 1960 ; Dadd,

TABLE 2. Comparison of feeding response of *S. gregaria* and *L. migratoria* towards.

Extract	Response observed	
	<i>S. gregaria</i>	<i>L. migratoria</i>
Wheat bran extract	+++++	++
Leaf extract of <i>Brassica oleracea</i> Var. <i>Botrytis</i>	++++	++
Leaf extract of <i>Zea mays</i>	+++	+++++
Leaf extract of <i>Lagerstroemia indica</i>	+++	Nibbled
Leaf extract of <i>Sorghum vulgare</i>	++	++
Leaf extract of <i>Agave americana</i>	++	±
Leaf extract of <i>Calotropis gigantea</i>	±	—
Leaf extract of <i>Azadirachta indica</i>	—	—
(Data from Mehrotra and Rao, 1966)		

1963 ; Mulkern, 1967 ; Schoonhoven, 1968). Presence of feeding stimulants for locusts have been recognised in ether and acetone extracts of leaves of some plants and that there may be more than one acceptants present in one plant (Goodhue, 1963, Mehrotra and Rao, 1966). Mehrotra and Rao (1966) not only demonstrated the presence of feeding stimulants in acetone extracts of various leaves for locusts but also showed that the feeding stimulant requirements of *S. gregaria*

and *L. migratoria* differ considerably (Table 2). Similarly, a comparison of six edible oils along with wheat bran extract (Table 3) again revealed that various oils differed significantly in their attractiveness to two locusts (Mehrotra and Rao, 1972).

TABLE 3. Comparison of feeding response observed towards various oils tested.

Name of Oils	<i>Schistocerca gregaria</i>	<i>Locusta migratoria</i>
Wheat bran extract	++++	++
Wheat germ oil	++++	++++
Olive oil	++±	++
Mustard oil	+±	±
Corn oil (Mazola)	+	+
Cotton seed oil	+	+±
Coconut oil	—	±
The values presented are the average of at least twenty separate feeding tests (Data from Mehrotra and Rao, 1972)		

The nutritive aspects of the host plant relationships have been amply emphasized by Thorsteinson (1960), Beck (1965), Beck and Reese (1976), McNeill and Southwood (1978). From their work it is evident that the nutrients in plants specially nitrogen (protein and/or amino acid) are important for the population build up. Relatively modest changes in both birth and survival rates due to nutrition available to insects may lead to changes in the rate of increase of its population. It is thus obvious that small nutritional differences in the host plants cause large changes in equilibrium population levels.

The other aspect which has hitherto received very little attention is the non-nutritional physiologically important aspects of plants and their effects on insects. Insects are also subject to developmental control by plants. It is known that Desert Locust swarms spend a large part of their time feeding upon dry and senescent vegetation and during this period they do not become sexually mature. It is only after rains when they have access to fresh green leaves that they become sexually mature, mate and lay eggs. Gibberellin content of the old senescent leaves is very low but that of young leaves is high. The gibberellins would, therefore, appear to fulfil some requirements for locust maturation (Carlisle *et al.* 1969). Another example of the plants effecting the development in insects can be seen from the fact that it is the physiological state of the plant which determines the diapause-aestivation in the maize stem borer, *Chilo partellus*. Recently evidence has been accumulating to suggest that the diapause syndrome in *Chilo*

partellus appears in stems containing relatively high water content and low protein contents. Diapause could be artificially induced in non-diapausing larvae if reared on aged maize stems. Superimposed upon this was the photoperiod (Scheltes, 1978). *Tryporyza* is also known to undergo dormancy because of dry or wet environment conditions (Rothschild, 1971). The effects on development of insects due to the physiological state of the plant puts the whole gamut of host plant relationship in the most interesting state. Here is one case where the biochemistry of the host affects the well being of the pest.

From the foregoing it would be seen that the insects host selection behaviour is affected by the sensory stimuli emanating not only from plants, which act as host, but also from general environment. The environmental factors influence metabolic processes of host as well as insects. This variable response, because of a number of sensory stimuli, affecting the insect can now be analyzed through systems analysis and could be fruitfully utilized for manipulating insect populations affecting agricultural production.

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**HOST-PARASITE RELATIONSHIP BETWEEN BATS AND
BATFLY, *BRACHYTARSINA SINHAI* VAZIRANI AND
ADVANI (DIPTERA : STREBLIDAE) VIEWED
FROM ECOLOGICAL ANGLE AND LIFE CYCLE**

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INTRODUCTION

Members of family Streblidae belonging to Diptera-Pupipara group are mostly ectoparasitic on bats exhibiting interesting host-parasite relationship. A good amount of work has been published on the host-parasite relationship between streblid flies and bats by Jobling (1938, 1939, 1949, 1951, 1954) ; Theodor (1957, 1968) ; Ross (1961) ; Wenzel (1966) and Maa (1968, 1971), but most of the works deal with the American, African and Australian streblids. Vazirani and Advani (1976) have reported *Brachytarsina sinhai*, a new streblid, ectoparasitic on *Rhinopoma microphyllum kinneari* Wroughton from Rajasthan. On the basis of two years survey of bats of Jodhpur and environs (Rajasthan) it was found that *B. sinhai* is specific to *R. m. kinneari* with rare occurrence on *Rhinopoma hardwickei hardwickei* Gray which generally roosts along with *R. m. kinneari*. In India, no attempt has been made so far, to know the factors which determine the host-parasite relationship between *R. m. kinneari* (the principal host) and *B. sinhai*. Earlier workers have discussed host-parasite relationship on the basis of host-parasite records, hence the necessity of some biological observations was felt by Jobling (1949). The present work covering the microclimatic factors of host, life cycle and ecological niche of fly is an endeavour in this direction.

MATERIAL AND METHODS

The ecological factors viz. temperature, humidity, light in the ecological niche of host, nature of roosting places of bats, size of colony, mode of living, availability of host, nature of fur, mode of flight were observed in field condition. Temperature and humidity were recorded normally at 10 a. m. The relative humidity was calcu-

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lated with the help of the "Table of Wet and Dry bulb thermometer readings with corresponding percentages of humidity" The size of colony of bats was noticed when the bats were at rest, to have an idea about their abundance. Most of the biological observations like deposition of offsprings, duration of intra-uterine development, pupal period, longevity of flies deprived of host and behaviour were made in laboratory while the mode of deposition of prepupa and host preference of fly were observed in field conditions.

RESULTS

Altogether 11 species of bats have been collected in and around Jodhpur but the flies *B. sinhai* were collected only from *R. m. kinneari* throughout the period of two years with some exceptions on *R. h. hardwickei*. Hence, the fly can be considered as oligoxenous parasite. Before discussing the suitability of the host, as an environment for survival and reproduction of the fly, a brief idea about the biology of fly is given below.

Biological Aspects of Fly

1. *B. sinhai* deposits prepupa on the wall of roosting place of host.
2. Egg and larval instars are nourished by the maternal tissue, *i. e.* milk glands.
3. Intra-uterine development lasts for nearly a month at 20-23°C.
4. Pupa cannot develop after 34°C.
5. Pupa period lasts for *ca.* 44 days in winter season (at 20-22°C) and *ca.* 18 days in summer (at 32-33° C.)
6. The longevity of adult fly deprived of host, is about 7 hours at 33-35°C.
7. The flies generally do not leave the host except for deposition of offspring or when the host is disturbed.

Factors Determining Host-Parasite Relationship

As the major part of life cycle of fly is completed away from the host, nature and climatic factors of roosting place and the structure and behaviour of host determine the host-parasite relationship. Some factors are dealt as followings.

A. *Temperature and Humidity* : From the life cycle it is clear that the continuity of life cycle is not possible if the temperature of roosting place of host is more than 34°C or 35°C, as the pupa cannot develop further. *Rhinopoma microphyllum kinneari* is so sensitive to temperature

of the roosting place that in summer months, when the temperature goes beyond 32°C or 33°C, the bats leave the roosting place (Fig. 1) particularly where the roosting place is restricted (like Surpura village,

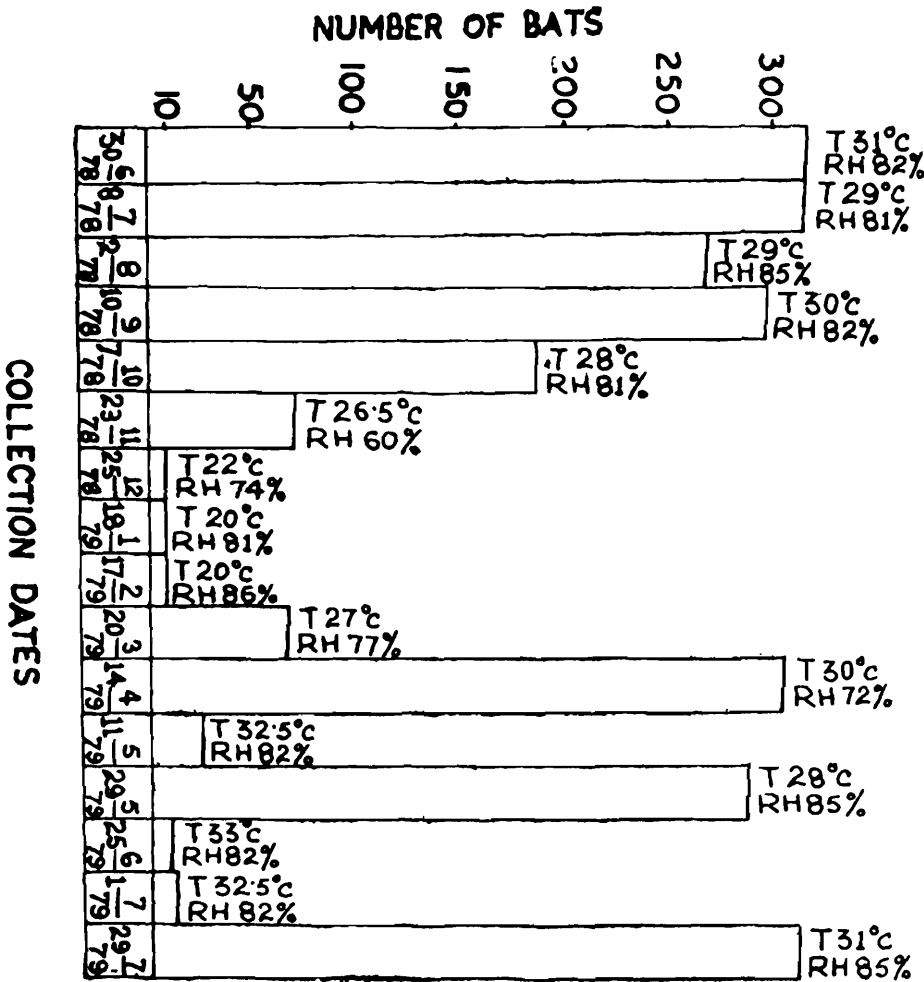


Fig. 1. Showing seasonal availability of *Rhinopoma microphyllum kinneart* at surpura (Jodhpur).

Jodhpur where the bats roost in a single dark room of the palace), otherwise enter deeper parts of cave, tunnels as in the case of Bhimbhadak and Mandore (Jodhpur) where the favourable temperature, *i. e.* 28-31°C is available. *R. h. hardwickei* which prefer more temperature than *R. m. kinneari*, were found at 33-35°C when the primary host of fly migrates. During such circumstances, the flies who had left the host for deposition of offspring or during the searching of host by newly emerged flies, might have infested *R. h. hardwickei* (a secondary host). Hence, the temperature affects the availability of host significantly in limited roosting places thus reducing the percentage of infestation and population density of parasites due to mortality, particularly in peak summer and winter months.

B. *Nature of Light* : It is observed that the fly is adapted to dark atmosphere as the fly flutters when exposed to light, so the fly is not adapted to such hosts like *Taphozous kachhensis kachhensis*, *Taphozous perforatus perforatus*, *Pteropus giganteus giganteus* and *Scotophilus heathi heathi* which prefer bright light whereas *Rhinopoma* prefers darker zones suitable for the fly.

C. *Nature of Roosting place and size of colony of host* : It is observed that *B. sinhai* which deposits its offsprings *i. e.*, prepupae on the walls of roosting place, prefers gregarious species of host. Gregariousness of the host helps the flies particularly newly emerged in searching the host for blood meal. As the flies reach the different parts of host and to another host by crawling rather than flying, the close contact between the hosts is advantageous and it avoids the possibility of missing the host as observed by Phillips (1924). *R. m. kinneari* being most abundant and gregarious species provides this condition suitable for fly. Eventhough, *T p. perforatus* is also gregarious but the flies do not prefer it due to its habit of tolerating more temperature and prone to migration. *Hipposideros fulvus pallidus* which are also somewhat gregarious but suspend apart from each other to the ceiling of the roosting place, and are very sensitive to disturbances.

D. *Availability of host* : The longevity of fly deprived of host being around seven hours at 33-35°C necessitates the availability of host for

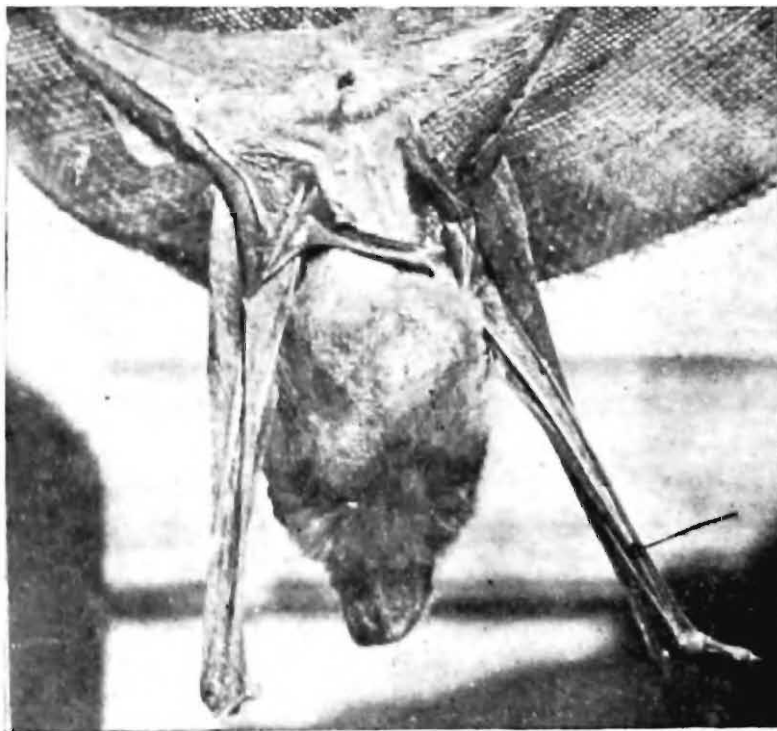


Fig. 2. Showing the folding of wing of *R. m. kinneari* at rest.

blood meal throughout the year for survival and continuity of life cycle. *R. m. kinneari* is mostly available throughout the year except in extreme summer and winter dates (Fig. 1) while most of the other hosts are not available in their roost throughout the year (as observed in Jodhpur and environs).

E. *Mode of sitting of host* : The mode of sitting of different species of bats also restricts *B. sinhai* to *Rhinopoma* in which the folding of wing during rest forms a sort of groove with the help of propatagium and fore arm which provides a good hiding place (Fig. 2) for the flies in winter season. The mode of sitting of other species of bats is unsuitable for the free movement of flies from one part of host to another and further there are chances of injury to the fly by the flapping activity of wing (as in case of *Taphozous*).

F. *Mode of flight and nature of fur* : Strong flyer hosts are not preferred by the fly, as there are more chances of detachment from

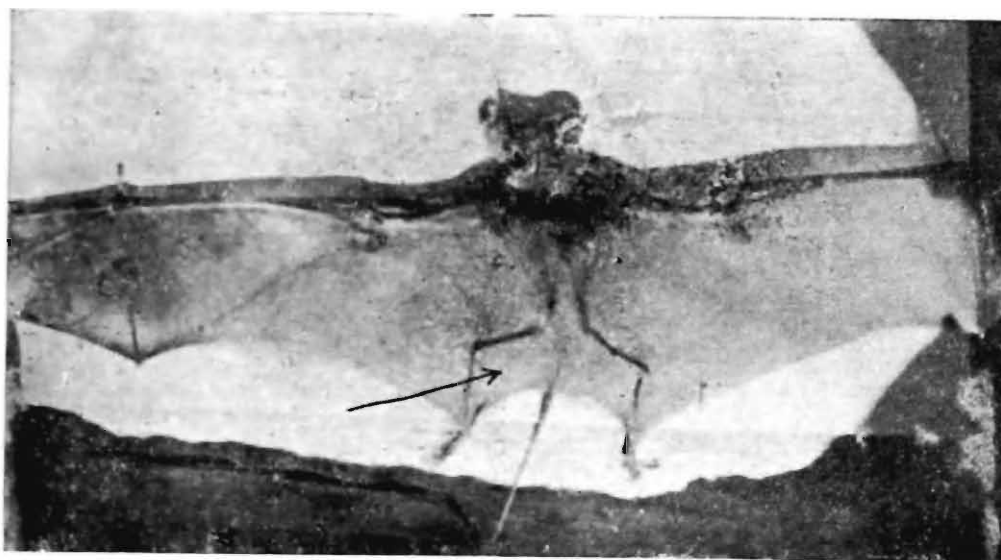


Fig. 3. Showing naked uropatagium of *R. m. kinneari*.

the host. *Rhinopoma* being a slow flyer and having restricted hunting territory, is suitable to fly for clinging. The naked uropatagium of *Rhinopoma* (Fig. 3) is preferred by the flies for sitting and through which the flies can move from one side to another on the body of host. In well fur-bodied bats like *H. f. pallidus* there is limited naked area for the fly to suck the blood and further it provides hindrances in movement.

DISCUSSION

Genus *Brachytarsina* Maa 1965 (= *Nycteribosca* Speiser 1900) has been recorded from hosts of families Rhinolophidae, Emballonuridae, Hipposideridae, Vespertilionidae, Nycteriidae and Rhinopomatidae (Jobling 1934, 1951). *Brachytarsina diversa* (Fraunfeld, 1857) is reported host specific on the bats of family Rhinopomatidae. In the present study also, the fly, *B. sinhai* is observed specifically parasitic on the bats of family Rhinopomatidae, particularly to *R. m. kinneari*. It can be said that the host specificity of streblid flies is not restricted to particular species, genera and families of hosts ; it may differ from one place to other as observed by Maa (1971), if the necessary ecological conditions are fulfilled by host. However, it is also true that the streblid flies prefer cave-dwelling gregarious bats as observed by Phillips (1924), Jobling (1949, 1951), Theodor (1957), Ross (1961), Wenzel (1966) and Maa (1971), but the host-parasite relationship is also determined by the life cycle of fly, as there is preference to roosting place not having more than 34-35°C for the proper development of pupa and the availability of host for blood meal as the longevity of unfed fly is very short. The mode of flight, nature of fur, mode of activities of host are perhaps the secondary factors which are responsible for the host specificity. The same is true for nycteribiid flies also (Funakoshi, 1977).

Jobling (1951) reported that streblid flies cannot exist on hibernating bats but *R. m. kinneari*, the principal host of *B. sinhai* hibernates in winter season (Sinha 1977) and can survive without food upto 3 months. But the flies instead of sitting on dorsal side of uropatagium hide themselves in the fur near abdomen particularly in ventral side of endopatagium. During these circumstances, the puparia deposited on walls can overcome the period of nonavailability of the host. (Fig. 1), as the pupae take about 44 days in hatching at 20-22°C. Jobling (1949) pointed out that the streblid flies do not infest solitary hosts but Ross (1961) reported the infestation of streblid fly *Trichobius corynorhini* on semi-solitary bat, *Plecotus townsendi*, which may be accidental but the population density of such flies would be too low if the infestation is not accidental. By viewing the hosts available in Jodhpur and environs it can be predicted that *B. sinhai* may also show its adaptability to *T. p. perforatus* and *R. h. hardwickei* as a regular host in addition to *R. m. kinneari*.

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SOME ASPECTS OF ECOLOGY OF LYGAEID BUGS
(HETEROPTERA : INSECTA) OF THE HOST PLANT
MADAR AND EFFECT OF THE LATTER ON
THE FECUNDITY OF *SPILOSTETHUS*
HOSPES (FABR.)

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In Eastern India two species of Madar, *Calotropis gigantea* and *C. procera* (Asclepiadaceae) serve as the abode for a number of bugs, beetles, grasshoppers, lepidopterous caterpillars, spiders and slugs. The bugs are represented by family Lygaeidae, Pyrrhocoridae and Cercopidae.

Three species of lygaeids *Spilostethus hospes* (Fabricius), *S. pandurus* (Scopoli) and *Graptostethus servus* (Fabricius) to a lesser extent have been considered in this paper for ecological studies. *Calotropis* spp. are widespread in India and so also the associated animals. *S. hospes* and *S. pandurus* are common associates and therefore occur in greater or lesser numbers in different regions and different seasons. Apart from the above mentioned species *Caenocoris nerii* (Germer) and *Tropidothorax fimbriatus* have been recorded from southern West Bengal.

The range of the host plants for both *S. hospes* and *S. pandurus* is wide however the major part of the year *Calotropis* spp. if present, are the first choice. *S. hospes* have been recorded on host plants *Sorghum valgarae* (Poaceae), *Gossypium* spp. (Malvaceae), *Vernonia cinerea* (Compositae), *Solenum nigrum*, *S. melongena* (Solanaceae) and *Sesbania* sp. (Papilionaceae). *S. pandurus* attacks about 18 species of plants belonging to 12 different families of which it may be obligatory to *Vernonia cinerea* (Compositae), *Hibiscus subdariffa* (Malvaceae), *Sesamum indicum* (Pedaliaceae) (Thangavelu, 1978 b) ; *Gossypium* spp. (Fletcher, 1917) ; *Vitis vinifera* (Vitaceae) (Issac, 1946) ; *Fagonia critica* (Zygophyllaceae) (Hamid and Ahmed 1972). For *G. servus* there is no accurate observation as its food (Maxwell-Lefroy, 1909).

Some aspects of ecology of these milkweed bugs as mating behaviour and occurrence (Thangavelu, 1978a), population frequency (Thangavelu, 1978b) and pest status of *S. pandurus* (Thangavelu, 1979)

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has been reported from southern region of Peninsular India. A general account of stadia of the immature stages and fecundity of *S. hospes* has been given by Malipatil (1979). Maxwell-Lefroy (1909) reported about the laying habit of *S. pandurus*; Bhattacharjee (1959), Hamid and Ahmed (1972) have furnished an account of nymphal stages and stadia.

The present study attempts to give an ecological account of the seasonal occurrence of *S. hospes* population, and a comparison of fecundity, hatching success, stadia and behaviour of *S. hospes* with *S. pandurus* that are little known from northern India, which has a much different climate from South India.

MATERIALS AND METHODS

The milkweed lygaeids were chiefly collected by means of spooter (aspirator); sweep-nets were sometimes used but with some disadvantage, since on operation, the whole colony of bug on a plant usually got disturbed. Hand picking were done at times when the bugs were engrossed in feeding.

Normally, *Calotropis* flowering twigs, dry *Calotropis* seeds and water were supplied in siphons as diets. Rearing jars (22 cm. × 13 cm.) covered with cloth were kept at a place which experienced sun through a part of the day.

Population incidence was recorded by counting every 3rd week the number of bugs present on a definite length of twig (15 inter-nodal distance or roughly one meter). Ten such twig lengths were chosen on ten different plants at Calcutta University Agricultural Campus, Baruipur, W Bengal.

OBSERVATION AND DISCUSSION

Population and spring emergence: Both *S. hospes* and *S. pandurus* were noted to be multivoltine. Each completed at least four to five overlapping generations. Of the two, *S. hospes* made an early emergence in springs (February) followed by *S. pandurus* after about a month. A few *G. servus* had also made their spring appearance along with *S. hospes*, but they never build up a strong population or were obligate to follicles or seeds of Madar.

At the outset a very thin population only of adult bugs were found feeding and mating on *Calotropis* weed. Hence it is supposed that all these bugs overwintered as adults. During winter in South India, Thangavelu (1978b) had observed sluggish adults of *S. pandurus* in reproductive diapausing phase under fig leaves and grasses at high

altitudes. However in North India with the onset of winter both *S. hospes* and *S. pandurus* completely disappeared from milk-weeds and were not traceable in the surrounding grass or litter. When reared in laboratory during winter the adults and nymphs of *S. hospes* were active and the adults also mated.

These observations may suggest the possibility of migration of these bugs as had been found true by Dingle (1968) for *Oncopeltus fasciatus*.

The population peaks *S. hospes* and *S. pandurus* were found to alternate on the host plant, Madar. This conforms to Thangavelu's observations (1978b) on the same species from S. India. The resource concentration effect as shown by Ralph (1977) for *O. fasciatus*, also works well with these species (Fig. 1). Places having the milkweed in scattered discontinuous pattern, however, showed a greater concentration of *S. hospes*, whereas places with a continuous thicket showed a



Fig.1

Fig. 1. Continuous thicket of *Calotropis*spp.

dominance of *S. pandurus*. The bugs and more often their nymphs preferred flowering shoot to vegetative parts; and dehised follicles to inflorescence. The *S. hospes* population showed several peaks. The maximum incidence of the bug were recorded in March-April, and by end of September the population dwindled. In October and early November when the follicles of madar plants have almost withered away a few bugs could be seen. With further progress of winter there was total disappearance of bugs as observed in the years 1978-79 and

1979-80 (Fig. 2). The complete absence of *S. pandurus* and *S. hospes* during winter and the population peaks of the latter in N. India were

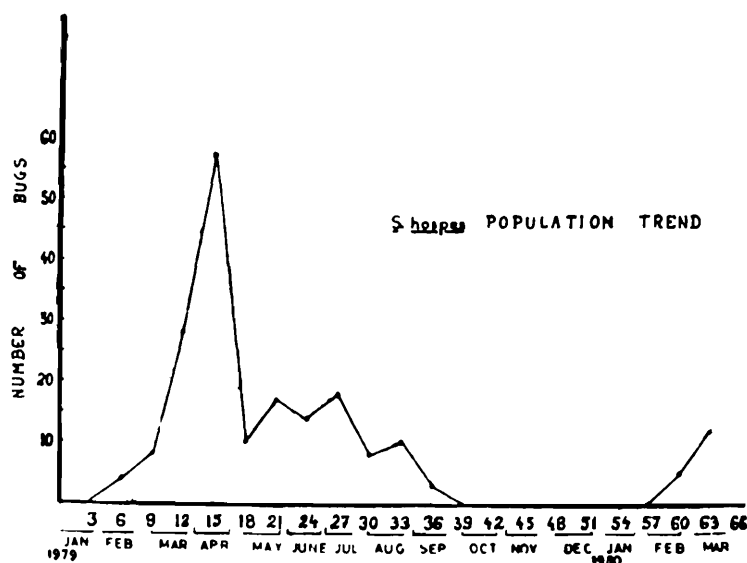


Fig. 2

Fig. 2. Population curve showing seasonal appearance of *S. hospes* (Fabr.)

contrasting to the relatively thin population of *S. hospes* in April-May and the maximum incidence during October-November in S. India (Thangavelu, 1978b).

Food, fecundity and stadia : Kugelberg (1973) had demonstrated for *Lygaeus equistris* that food plant significantly affected fecundity, oviposition-period and longevity of females.

S. hospes and *S. pandurus*, when kept on a diet of *Calotropis* seeds, its fresh twigs and water laid a fair number of eggs and also had a moderate longevity.

Eggs laid		Longevity ♀		
Average	Range	Average	Range	
150.08	(75-232)	24	(15-32)	
	Exception 467		Exception 42	<i>S. hospes</i>
385	(161-989)	21	(17-30)	<i>S. pandurus</i>

It was observed for *S. hospes* that the above diet when deficient in fresh water did not impede the rate of laying, but the bugs when kept on diet of figs (*Ficus cunius*) and water (without *Calotropis* seeds) failed to lay eggs in all seasons and had a reduced longevity. However, the moulting of the nymphs and the mating activity of the adults went unabated.

S. hospes pairs when kept on a diet of dry milk weed seeds, water

and fresh pieces of apple laid normal eggs. Again the bugs when kept on the same diet but lacking in *Calotropis* seeds showed inspite of equal vigour of mating, no laying activity. However, there was marked increase in the longevity of the adults, and the nymphs also moulted. On such a diet the adult bugs as well as some of the nymphs could be kept active throughout the winter.

Sweet (1964) opined that fecundity in laboratory could not be compared with that in the field, where several factors such as availability of food, weather, predation and parasitism would adversely affect that. On host plants other than *Calotropis* species where the milkweed bugs breed, availability of seeds seems important for normal fecundity. *S. pandurus* that breeds on other host plants as gingelly, *Vernonia* & *Hibiscus subdariffa* (Thangavelu, 1978b) are known to probe deep into the fruits to reach the seeds.

Malipatil (1979) had given an account of the fecundity and nymphal development of *S. hospes* when the bugs were reared on husked sunflower seeds, but here no natural infestation of sunflower seeds were observed, despite sunflower cultivation being carried on side by side with the milkweeds that housed *S. hospes*.

S. hospes and *S. pandurus* when kept on the same diet (milkweed

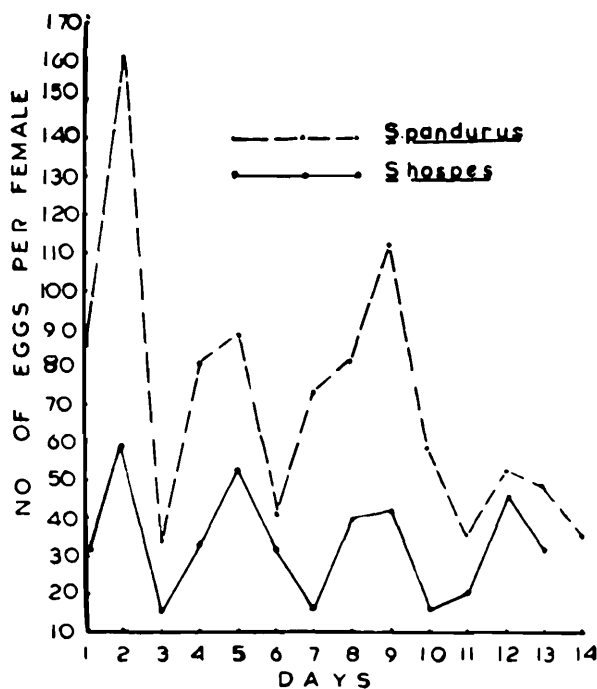


Fig. 3

Fig. 3. Oviposition trend of *S. hospes* (Fabr.) and *S. pandurus* (Scopoli)

seeds, twigs and water) and under almost identical conditions show similar egg laying trends but *S. pandurus* laying greater number of eggs

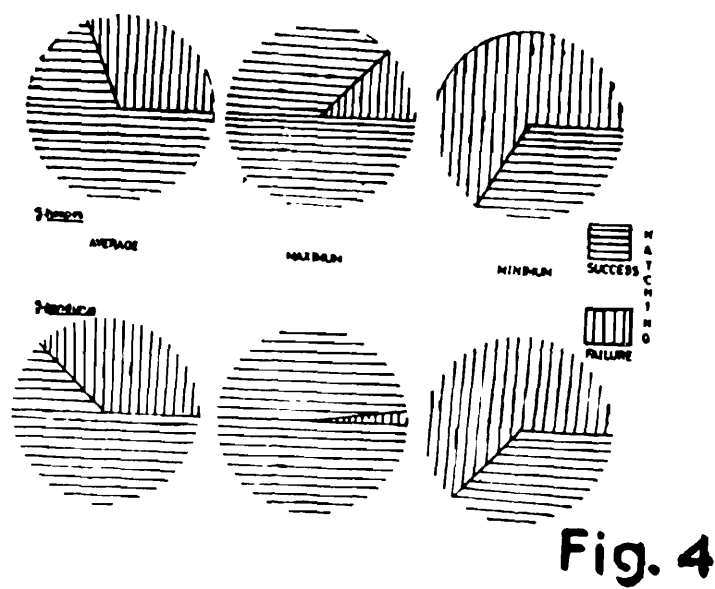


Fig. 4. A comparison of successfully hatched eggs of *S. hospes* (Fabr.) and *S. pandurus* (Scopoli).

than *S. hospes* (Fig. 3). The zygotic mortality or otherwise the hatching success varied for the two species (Fig. 4).

Hatching success		
Average	Maximum	Minimum
69%	87.5%	34% <i>S. hospes</i>
62%	98%	36.6% <i>S. pandurus</i>

On an average *S. hospes* showed a more successful hatching than *S. pandurus*. The nymphal stadia and their total developmental periods (in days) of the two bugs also showed much difference (Figs. 5, 6, 7).

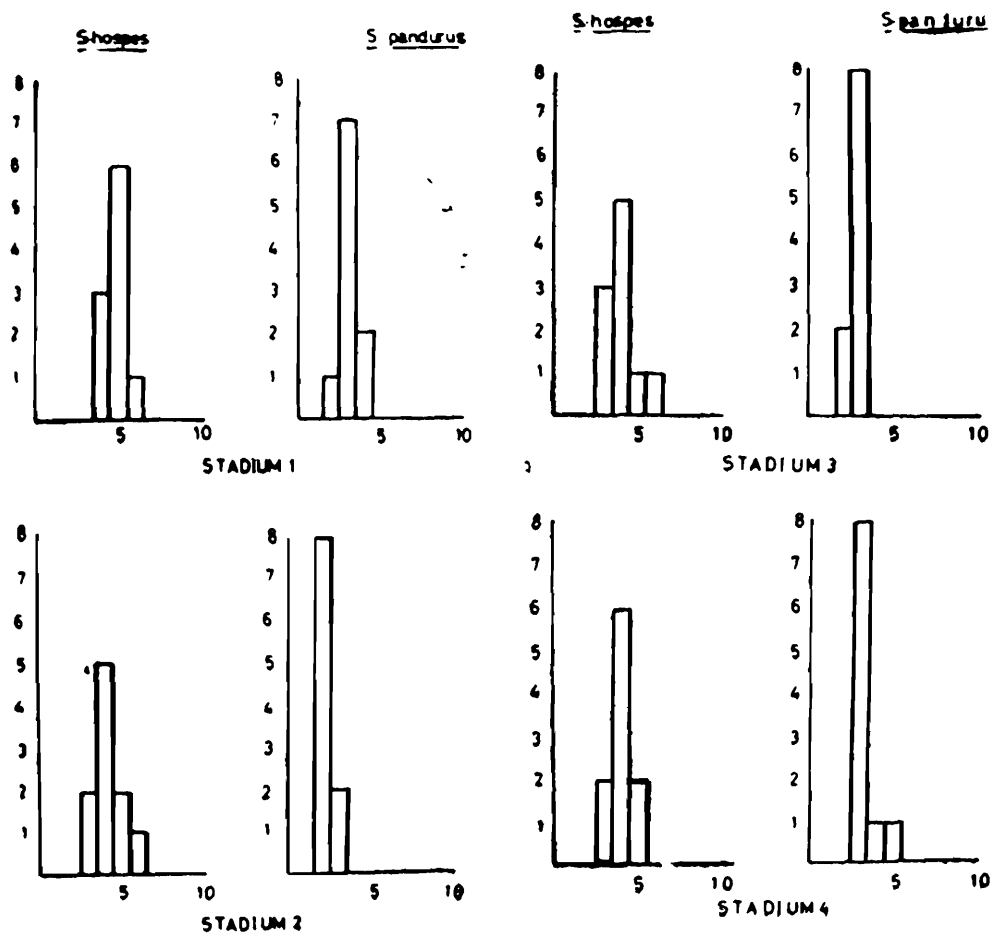


Fig. 5

Fig. 6

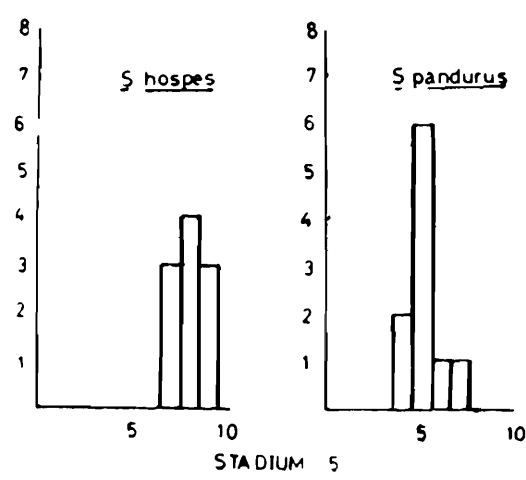


Fig. 7

Figs. 5, 6, 7. Comparison of stadia of ten immature stages of *S. hospes* (Fabr.) with *S. pandurus* (Scopoli). Ordinates- no. of observations; Abscissae- time in days.

	Instar 1	Instar 2	Instar 3	Instar 4	Instar 5	Total
<i>S. hospes</i>						
Mean (Range)	4.8 (4-6)	4.2 (3-6)	4.0 (3-6)	4.0 (3-5)	8.0 (7-9)	25.0(22-28)
<i>S. pandurus</i>						
Mean (Range)	3.1 (2-4)	2.2 (2-3)	2.8 (2-3)	3.3 (3-5)	5.1 (4-7)	16.5(15-20)

The cannibalism in late instar had been reported for *S. pandurus* (Bhattacharjee, 1969). Over crowding was thought to be the cause for that. But it has been noticed that in spite of a fair supply of food and water in the mixed cultures, the fourth, and fifth instars and the adults of both *S. hospes* and *S. pandurus* resort to cannibalism. It was found true that the absence of either food or water or both increased the propensity of cannibalism. Normally, the weakest or the most sluggish nymphs of earlier or same instar were attacked and sucked. So this might be a means for population control, in case of overcrowding. Occasionally, the adults (sometimes the laying female) would feed on the eggs, and earlier instars would suck the body fluid of a dead nymph or adult.

In mixed rearing at laboratory on extreme starvation *S. hospes* adults were found sucking dying adults of *S. pandurus*.

The first and second instars of milk-weed bugs that mostly fed in the flowering or tender leafy shoots often showed colonial feeding habit. Such feeding activity of these tiny nymphs in congregation at or around a spot can be presumed to be of temporary benefit as had been indicated by Thangavelu (1978a) "Congregation of nymphal instars at the feeding site may act as a stimulus for intensive feeding operation" The relatively slow moving first and second instar nymphs might also gain extra safety by bunching together which has been discussed later.

A peculiarity in feeding habit of the adults and advanced nymphs of *S. hospes* was that they sucked plant sap only at the regions of leaf blade where leaf veins were present. The seed defence or stealing behaviour was quite evident amongst the nymphs and the adults of both *S. hospes* and *S. pandurus*. It was quite common to find both the species to feed simultaneously on the seeds of the same follicle or even at times compromising to share the same seed.

Enemies and defence : *S. hospes* or *S. pandurus* had been observed to have no regular enemy or predators in the field, excepting Hoffmans report (1932) where *Francolinus pondicerianus* had been observed to take away *Lygaeus hospes* (*S. hospes*).

Thangvelu (1978b) reported *S. hospes*, *S. pandurus* and *C. nerii* which had the plants of Asclepiadaceae as first choice showed less preference to the members of Compositae and Apocynaceae at host plants. Despite conspicuous coloration these bugs had not been observed to be attacked by insectivorous birds and lizards (*Calotes versicolor* (Daudin 1802) that abound there (Fig. 8). The unpalatability of these bugs may be attributed to the findings of Voneuw, Reichstein



Fig.8

Fig. 8. *Calotis versicolor* (Daudin) sharing the same abode of the milkweed bugs.

and Rothschild (1971) for *Caenocoris nerii* & *S. pandurus* ; Scudder and Duffey (1972) for bright coloured species of Lygaeinae and finally by Abushama and Ahmed (1976) *S. pandurus* all of whom had advocated that the bugs feeding on the plants of the family Asclepiadeceae or Apocynaceae sequestered a type of heart poison (cardiac glycoside) which were incorporated in special series of prothoracic glands known for their defensive secretion. So the bright red hue of these bugs might be taken as warning colouration. Exposing conspicuous flashes is a common weapon of defence among gregarious animals (Burton 1977). A close pact clutter of first and second nymphs through jinking as one body might threaten an intruder, or the latter might grow conscious of the scarlet red warning colour or may avoid the mass, apprehending an accidental collision.

Dead bugs when kept within the access of foraging ants were seldom carried away, whereas live bugs when reared for long simply on apple diet were attacked and torn by ants *Bothromyrmex myops* Forel.

Economic consideration : The depredation of a huge number of milk-weed seeds by *S. hospes* and *S. pandurus*, while they remain stacked in a part dehiscid follicles of *Calotropis*, might be of some importance in controlling the noxious weed. It was observed that the seeds which were thoroughly sucked up by bugs seldom germinated. However, a biological control method of the milkweeds by encouraging the bug population cannot be recommended as these bugs have also the potentiality to change into crop pests.

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EFFECT OF HOST CONDITIONS ON THE MORPHOLOGY OF SOME APHID SPECIES (INSECTA : HOMOPTERA)

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INTRODUCTION

Morphology is the end product of physiological activities initiated by the genome and modified by the environment. As a consequence the change in the physiology in the immature stage is likely to result in a change in morphology.

Aphids are long known as obligatory parasite of plants. The assumption that physiology of a plant is reflected in the morphology of the insects, may lead one to assume that at least the polyphagous species of aphids will show variation in morphological characters according to the plant species infested by them. Such variations may result in the find of a number of bio-types of a particular species, e. g., *Myzus persicae* (Sulzer), *Aphis gossypii* complex etc.

If the assumption that different plant species may alter at least to a certain extent the morphological characters, than it becomes rational to presuppose that the aphid species which infest the sub-aerial and the aerial parts of a plant in a locality during more or less the same time period will show differences in the morphological characters when the aerial and the sub-aerial populations of the species are taken into consideration.

Keeping these facts in view, the different morphological characters of taxonomic importance have been analysed for three aphid species, e. g. *Asiphonella cynodonti* (Das) (Pemphiginae), *Ceratoglyphina bambusae bengalensis* Ghosh (Hormaphidinae) and *Rhopalosiphum maidis* (Fitch) (Aphidinae) occurring in Kalimpong in darjeeling district of West Bengal. The first one of these infests grasses, the second different species of bamboos and the third the maize.

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MATERIALS AND METHOD

For the three aphid species, e. g., *R. padi*, *A. cynodonti* and *C. bambusae bengalensis* apterous viviparous females, collected both from roots and shoots of their host plants, have been taken into consideration. All the aphid samples were collected in Kalimpong, darjeeling district of West Bengal. For the first named species collection was made during January-February, for the second and the third species the periods was March-April. Measurements of the different bodily parts, which are considered important for taxonomical study, were taken from specimens after these were processed in the usual manner for the microscopical studies. For such purpose 20 individuals of each species were considered. 10 of these were shoot infesting individuals and 10 root infesting ones. The data obtained were statistically analysed in order to observe whether the variations, if any, are statistically significant using 't' test (vide Mathew, 1966). Besides morphometric data, life colour of the root and shoot infesting individuals of the three species was noted.

OBSERVATIONS

The life colour of the individuals of the apterous viviparous females of *R. padi*, *A. cynodonti* and *C bambusae bengalensis* are given in. Table 1.

TABLE 1. Colour difference in the root and shoot infesting individuals of *R. padi*, *C. bambusae bengalensis* and *A. cynodonti*

	<i>R. padi</i>	<i>C. bambusae bengalensis</i>	<i>A. cynonti</i>
Root	Greenish brown	Brown	Yellowish bronwn
Shoot	Dark green	Yellowish	Pale green

The table reveals that the root infesting individuals of the three species show a tendency to appear brown while the shoot infesting individuals green.

The statistical analysis of the morphometric data of the apterous viviparous females of *R. padi*, *A. cynodonti* and *C bambusae bengalensis* are provided in Table 2.

From the above table it appears that in case of all the three species the root infesting individuals differ significantly from the shoot infesting ones in respect of body length, body width, antennal length and length of hind tibiae. In the first case such difference is significant at 0.05%,

TABLE 2. Statistical analysis of some taxonomically important morphometric data of root and shoot infesting individuals of *A. cynodonti*, *C. bambusae bengalensis* and *R. padi*.

Characters	A. CYNODONTI				C. BAMBUSAE BENGALENSIS				R. PADI				D.F. (n-1) (where 'n' denotes size of sample)	Level of significance 't' test
	Root		Shoot		Root		Shoot		Root		Shoot			
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.		
	(mm)		(mm)		(mm)		(mm)		(mm)		(mm)			
L. body	1.951	± 0.873	1.934	± 0.062	2.342	± 0.098	2.082	± 0.103	2.071	± 0.134	2.055	± 0.096	19	0.05
W. body	1.256	± 0.013	1.222	± 0.023	1.928	± 0.087	1.591	± 0.076	1.353	± 0.826	1.265	± 0.065	19	0.1
L. ant.	0.725	± 0.043	0.693	± 0.032	0.514	± 0.013	0.436	± 0.022	1.323	± 0.068	1.283	± 0.082	19	0.1
L. ant. III.	0.186	± 0.011	0.167	± 0.010	0.243	± 0.008	0.193	± 0.009	0.352	± 0.012	0.018	± 0.007	19	0.1
U. r. s.	0.073	± 0.001	0.067	± 0.001	0.076	± 0.001	0.067	± 0.002	0.109	± 0.003	0.099	± 0.002	19	0.6
h. t. 2	0.183	± 0.004	0.156	± 0.005	0.111	± 0.002	0.102	± 0.002	0.106	± 0.003	0.107	± 0.002	19	0.7
L.h. ant. terg.	0.022	± 0.003	0.023	± 0.002	0.043	± 0.003	0.044	± 0.001	0.018	± 0.002	0.019	± 0.002	19	0.3
L. h. 7th terg.	0.032	± 0.002	0.031	± 0.002	0.111	± 0.005	0.098	± 0.004	0.028	± 0.004	0.033	± 0.003	19	0.8
L.h. 8th terg.	0.033	± 0.001	0.022	± 0.001	0.136	± 0.008	0.111	± 0.007	0.035	± 0.003	0.041	± 0.005	19	0.9
L. siph.	—	—	—	—	—	—	—	—	0.025	± 0.007	0.256	± 0.005	19	0.9
L. cauda	—	—	—	—	—	—	—	—	0.152	± 0.003	0.155	± 0.004	19	0.9
b. d. III	0.056	± 0.002	0.043	± 0.002	0.033	± 0.003	0.032	± 0.002	0.029	± 0.002	0.026	± 0.003	19	0.9
L. p. t.	0.076	± 0.004	0.073	± 0.004	0.054	± 0.002	0.044	± 0.002	0.418	± 0.022	0.415	± 0.014	19	0.7
L. claw	0.066	± 0.003	0.056	± 0.002	0.032	± 0.002	0.033	± 0.003	0.034	± 0.002	0.039	± 0.003	19	0.7
L. h. tib.	0.579	± 0.036	0.509	± 0.023	0.536	± 0.037	0.376	± 0.044	0.166	± 0.003	0.242	± 0.004	19	0.2

L. body=Length of body ; W. body=Width of body ; L. ant.=Length of antenna ; L. ant. III=Length of antennal segment III ; U. r. s.=Length of ultimate rostral segment ; h. t. 2=Length of 2nd hind tarsus ; L. h. ant. terg.=Length of longest hair on anterior tergites ; L. h. 7th terg.=Length of longest hair on 7th tergite ; L. h. 8th terg.=Length of longest hair on 8th tergite ; L. siph=Length of siphunculus ; L. cauda=Length of cauda ; b. d. III=Basal diameter of antennal segment III ; L. p. t.=Length of processus terminalis ; L. claw=Length of claw on hind tarsi ; L. h. tib.=Length of hind tibiae.

TABLE 3. Statistical analysis of the value of the ratio of some body parts of root and shoot infesting individuals of *A. cynodont*, *C. bambusae bengalensis* and *R. padi*.

Ratios	A. CYNODONTI				C. BAMBUSAE BENGALENSIS				R. PADI				D.F. (n-1)	Level of significance 't' test
	Root		Shoot		Root		Shoot		Shoot		Root			
	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.		
	(mm)		(mm)		(mm)		(mm)		(mm)		(mm)			
L. body/W. body	1.176	0.222	1.283	± 0.034	1.613	± 0.147	1.532	± 0.024	1.553	± 0.172	1.576	± 0.045	19	0.1
L. ant/L. body	0.232	0.032	0.224	± 0.014	0.617	± 0.053	0.662	± 0.006	0.367	± 0.007	0.381	± 0.013	19	0.1
L.p.t./L. base	2.425	0.196	2.136	± 0.125	1.485	± 0.097	1.343	± 0.138	5.524	± 0.072	4.502	± 0.083	19	0.3
L.h.ant.III/b.d.III	0.286	± 0.018	0.286	± 0.022	1.573	± 0.108	1.503	± 0.102	0.597	± 0.054	0.656	± 0.053	19	0.3
U. r. s./h. t.2	0.387	± 0.012	0.425	± 0.007	0.633	± 0.018	0.603	± 0.028	1.138	± 0.018	1.032	± 0.024	19	0.4
U. r. s./L. h. tib.	0.102	± 0.142	0.117	± 0.163	0.134	± 0.173	0.182	± 0.205	0.132	± 0.161	0.113	± 0.132	19	0.2

L. body/W. body=Length of body/Width of body

L. ant./L. body=Length of antenna/Length of body

L. h. ant. III/b. d. III=Longest hair of antennal segment III/
basal diameter of the segment

L. p. t./L. base=Length of processus terminalis/Basal length of
antennal segments VI

U. r. s./h. t. 2=Length of ultimate rostral segment/length 2nd
hind tarsus

U. r. s./L. h. tib=Length of ultimate rostral segment/Length
of hind tibiae

level and in the rest three cases at 0.1% level. In respect of these characters it is observed that the root infesting individuals appear bigger in size than the shoot infesting ones. Further it is observed that for all the three species the hind tibiae of root infesting apterae viviparae are longer than the shoot infesting ones but statistically this difference does not seem to be very much significant.

Consideration of the value of the ratio of different body parts as indicated in the table 3 reveals that the root infesting individuals vary significantly from the shoot infesting ones when the ratios like length of body : width of body ; length of antenna : length of body and length of ultimate rostral segment : length of hind tibiae are considered (Table 3).

DISCUSSION

All the above named species appear to breed anholocycly in Kalimpong conditions, West Bengal since no sexual has so far been reported from the area. Moreover, these species are not heterocious.

From the available data it appears that none of these species produce alate individuals when it infest the sub-aerial parts. It may be that the stimuli needed for wing production in aphids are not sufficiently active when the species remain below the ground level. Mittler (1973) using artificial diet observed that the concentration of some vitamins including ascorbic acids and amino acid like proline have considerable effect on wing production in aphids.

The morphometric data on taxonomically important characters of the three species reveal that the root infesting individuals are bigger than the shoot infesting ones. From this data (Table 2) one is inclined to surmise that roots provide better nutrition at least in respect of minerals, vitamins and nitrogenous compounds which, in turn, influence the size of the individuals produced by the aphids in the root system of the host plant which consists of more active tissues. Dixon and Glen (1971) working with *R. padi* opined that in nature the neotenous morphs can better exploit the good conditions normally associated with young and developing plant tissues by developing faster and becoming bigger and more fecund.

Further, the root infesting individuals of the three species possess longer antennae since these three species have very restricted host plants. The nutrient status of the plant parts infested is determined

more by flavour discrimination and hence longer antennae in the root infesting individuals may be attributed to finding of nutritionally more efficient plant parts. That flavour discrimination plays a more important role in host determination by *R. padi*, a host restricted aphid species, has been pointed by Dixon (1971).

At the moment it is hard to make any definite comment about longer hind tibia in the root infesting individuals.

However that the host plant either itself or conjointly with other biotic or abiotic factors influences at least to a certain extent the morphology of aphids, is evident from the present study. How and at what level the host plants interact with aphids remain to be worked out at depth.

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HOST AS AN ENVIRONMENT IN THE ECOLOGICAL
SUCCESSION OF INSECT BORERS IN FRESHLY
FELLED TREE TRUNKS

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INTRODUCTION

Wood is a unique raw material which is continuously renewable and completely degradable without harmful effect to the environment. Considerable degradation of wood by insects, which is faster in the tropics than in the temperate regions, takes place soon after a tree is felled. However, the rate of degradation varies widely according to the tree species involved. There are some tree species which have sufficient ability to resist attack of insect borers after felling, while there are numerous tree species that may be attacked readily and quickly by insects the moment they are felled. The insect borer attack to freshly felled tree trunks follows an ecological sequence depending primarily on the moisture content of the wood, availability of suitable oviposition sites and food material. In this paper, the ecological succession of insect borers in freshly felled tree trunks as influenced by the host environment has been described.

Factors determining ecological succession of borers :

The most important ecological characteristics of a freshly felled tree that govern attractiveness to insect borers are its high moisture content due to sap and the presence of bark with varying thickness. After lapse of some time even where moisture conditions apparently remains favourable due to absorption of atmospheric moisture, the wood becomes unattractive to those borers that attack freshly felled tree trunks. This is attributable to the changes of physical, chemical and biological conditions within the wood (Graham 1940). With the passage of time, gradual loss of moisture takes place during the process of natural seasoning. As time passes, the felled tree trunk is also invaded by decay organisms. Starch in the sapwood is an important factor governing the infestation of drywood borers, as they are dependent on starch for their larval development.

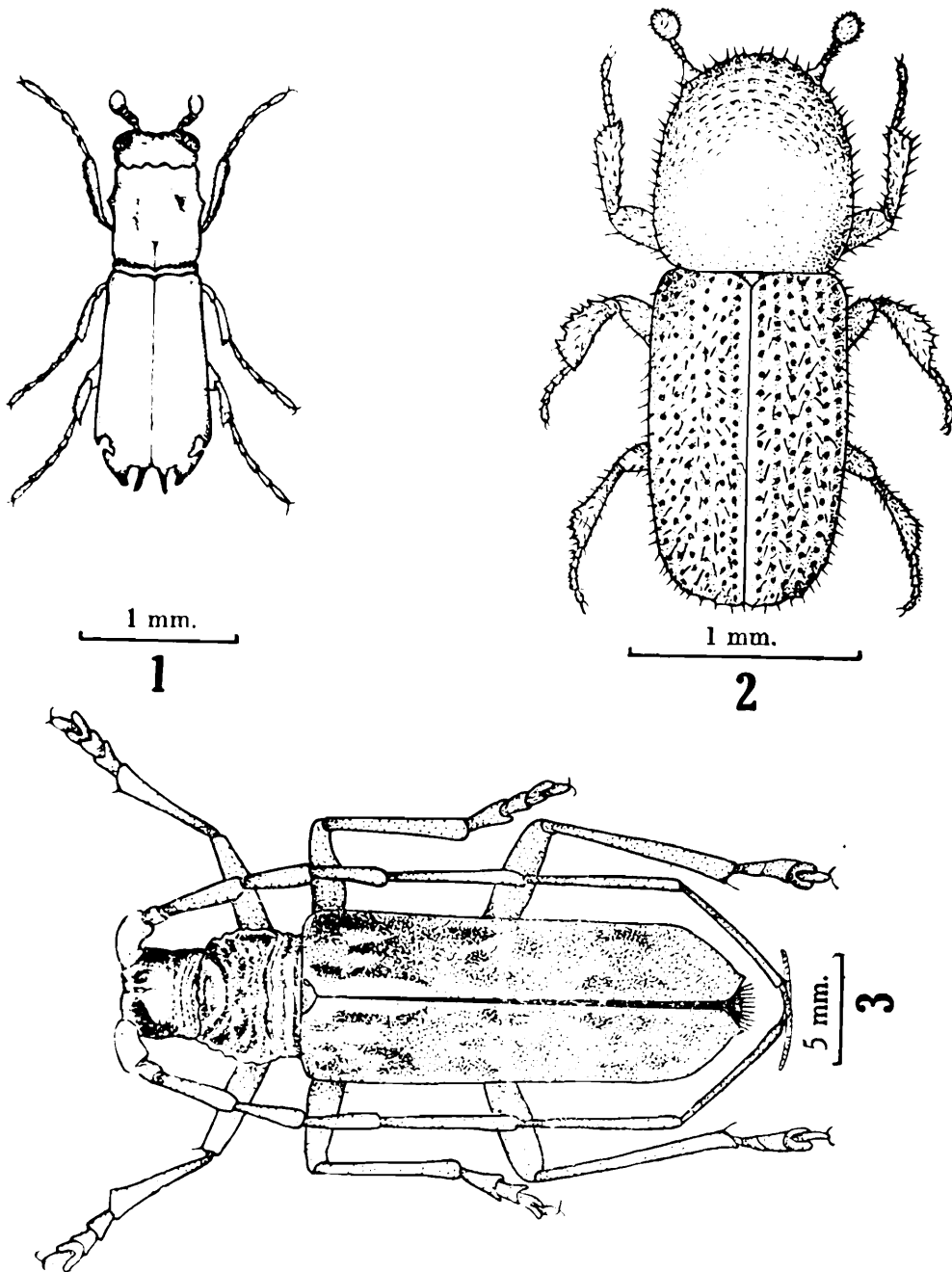
Ecological succession of borers in felled tree trunks :

(a) *Ambrosia beetles :*

Soon after felling, the green tree trunk is invariably invaded by ambrosia beetles (pinhole borers, Families Platypodidae and Scolytidae). Since ambrosia fungus is consumed by the developing larvae for their growth and survival, only tree trunks with high moisture content due to tree sap will be attacked, as ambrosia fungus cannot grow in wood with low moisture content. Thus, the attack will continue as long as the logs and boles remain moist and sappy. The attack by ambrosia beetles or pinhole borers is easily recognised by long streaks of fine wood-dust ejected out of the initial boring holes made by the females on the surface logs, (males cannot bore tunnels due to atrophied thoracic muscles) (Beeson 1941, Sen-Sarma 1980). The minute circular holes (up to 4.0 mm in diameter) are stained black due to growth of fungus in the tunnels. Unlike *Lyctus* attack, no wood-dust occurs in the larval tunnels, as the larvae feed only on ambrosia fungus and not on wood.

Further, most pinhole borers are attracted to freshly felled tree trunk by olfactory sense (Brown 1953, Bletchly 1960). Therefore, the intensity of invasion by these borers is determined by the thickness of the bark, trees with thick bark, in general, being less susceptible. Removal of bark of these trees after felling is liable to higher intensity of attack. In regions with definite winter season, adults take to flight in early spring. But in the tropics with no clear-cut winter season, adults emerge throughout the year depending upon the availability of food material. In most species, the life-cycle is short (between 15-21 days) and therefore, infestation spreads very rapidly.

Important species of pinhole borers and ambrosia beetles belong to the genera *Crossotarsus*, and *Plytypus* (*Platypodidae*) and *Xyleborus* (*Scolytidae*), *Crossotarsus saundersi* Chap. (Fig. 1) is a common pinhole borer in regions of moderate rainfall but less frequent in dry zones. It attacks freshly felled tree trunks of as many as one hundred tree species. Beetles are on wing most abundantly during the autumn and the spring. *Platypus solidus* Walk. is more frequent in dry zones. This species is polyphagous, infesting freshly felled logs of nearly fifty tree species. *Xyleborus perforans* Woll. (Syn. *X. testaceus*) (Fig. 2) is the commonest pinhole borer throughout the Indo-Malyan Region. In India, it is widely distributed in Andaman Islands, Assam, Madhya Pradesh, Tamil Nadu, Uttar Pradesh and West Bengal. It is highly polyphagous, infesting about one hundred and fifty timber species. The emergence of



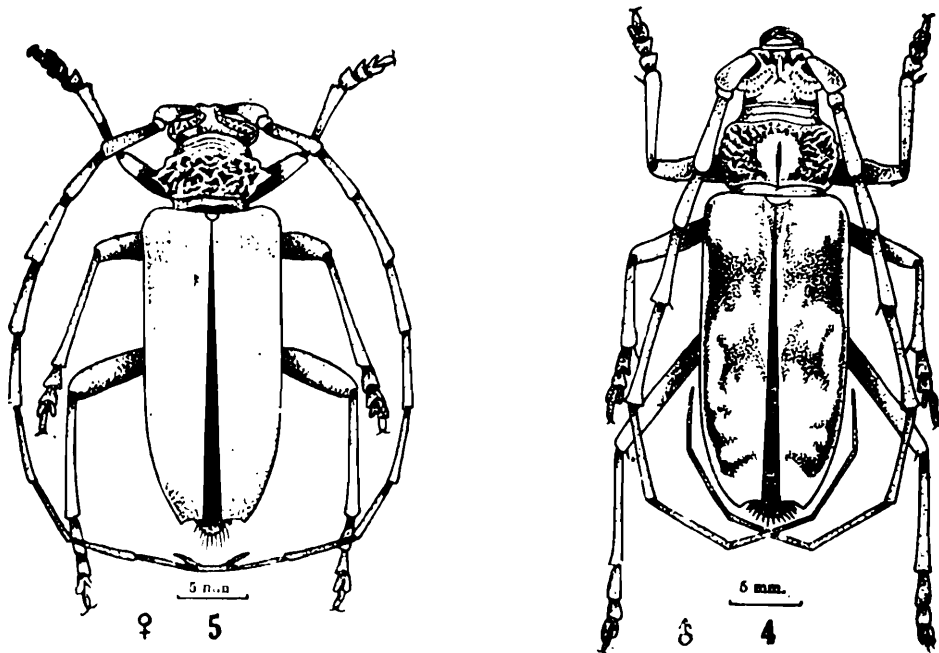
Figs. 1. *Crossotarsus saundersi* Chap., in dorsal view. 2. *Xyleborus perforans* Woll., in dorsal view. 3. *Aeolesthes holosericea* (Fab.), female, in dorsal view.

adults occurs throughout the year. However, peak periods of abundance are in October-November and February-April (Beeson 1941, Sen-Sarma 1980).

(b) *Borers attacking moist tree trunks with bark :*

Next to ambrosia beetles in the ecological succession are the borers that attack tree trunks with bark condition, as eggs are laid on the bark and bast of the logs. These borers belong to Buprestidae, Cerambycidae,

Lamiidae and Curculionidae. Of these, Cerambycidae and Lamiidae are the most destructive pests of unbarked logs which will be discussed first.



Figs. 4. *Acolesthes holosericea* (Fab.), male, in dorsal view. 5. *Plocaederus obesus* Gahan, in dorsal view.

Longicorn female beetles lay eggs on the inner surface of the bark of felled tree trunks primarily through cracks and injuries on the bark caused during felling operations or through slits gnawed by adult beetles. Life-cycle of these beetles varies widely in India. However, for most species it ranges from less than one year to more than a year. Emergence of adults takes place in summer in the subtemperate region and in pre-monsoon, monsoon and post-monsoon period in the tropical region. *Acolesthes holosericea* (Fab.) (Figs. 3 & 4), *Batocera rufomaculata* Degear, *Macrotoma crenata* (Fab.), *Plocaederus obesus* Gahan (Fig. 5) and *Xylotrechus smei* Lop. & Gory (Fig. 6) are some of the most injurious polyphagous longicorn borers. *Glenia spilota* Thom. is monophagous and restricted to unbarked logs of *Bombax ceiba*.

Flatheaded borers (Buprestidae) rank in importance next to longicorn beetles. *Belionota prasina* Thunb. is a serious borer causing extensive damage to both sapwood and heartwood in the form of wide and long tunnels. *Buprestis geometrica* Cast & Gory is very injurious to logs of *Pinus roxburghii* and *P. wallichiana* reducing the affected log almost into dust by the borer larvae. *Melanophila coriacea* Kerr. is a polyphagous sapwood borer attacking several species of wood.

Weevil borers (Curculionidae) damage sapwood only, boring deep

into wood where sapwood and heartwood are not differentiated. The commonest weevil borers belong to the genera *Mecistocerus* (e.g. *M. fluctiger* Fst.), *Rhadinomerus* (e.g. *R. diversipes* Mshl.) and *Sipalus* (e.g. *S. hypocrita* Boh.).

Several of the borers belonging to above groups of insects damage moist wood. They attack felled tree trunks even after one year if the tree trunk remain moist as a result of contact with the ground or other moist material. The insects that attack and bore into these moist wood are usually associated with wood decaying microorganisms which provide suitable conditioned food for the insect inhabitants (Graham 1940). Unbarked logs are not attacked.

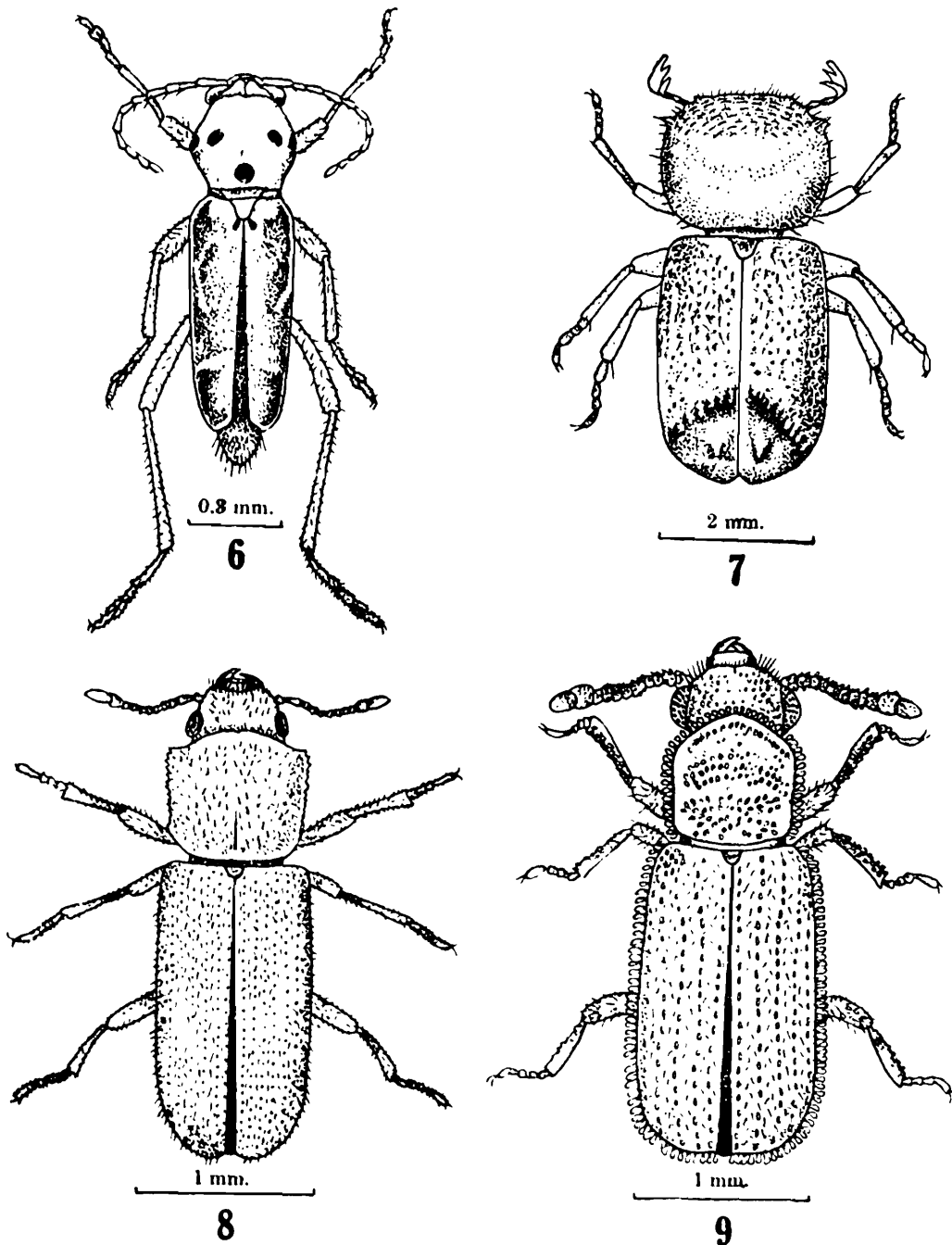
(c) *Drywood borers* :

The felled tree trunks, cut logs, etc. are attacked by drywood borers (powderpost-beetles) (Bostrychidae and Lyctidae) when the moisture content of the logs has been sufficiently reduced (ca. 25-40%). These borers are, in general, polyphagous. The attack is restricted to only sapwood containing starch which along with certain carbohydrates (disachharides and a polysachharides) and some protein is the main food utilised by larvae, cellulose, pentosans and lignin remaining unchanged after passing through the larval gut (Parkin 1940, Tooke 1949). Borers of Lyctidae attack seasoned wood (moisture content 10-15%). Leaching of soluble sugars by means of water reduces the susceptibility of wood to a considerable degree (Sen-Sarma 1980).

There is an important difference with regard to oviposition behaviour of females of Bostrychidae and Lyctidae. While the females of Bostrychidae must bore inside the wood to lay eggs, females of Lyctidae can lay eggs only on a cut and exposed wood vessel by inserting their long ovipositor. Non-porous wood (conifers) or wood with pores less in diameter than the ovipositor are immune to attack by powder-post beetles (Hickin 1963, Sen-Sarma 1980).

Schistoceros anobioides Wat. is a borer of sapwood of logs and occurs throughout the plains of northern and Peninsular India. *Sinoxylon anale* Lesne (Fig. 7) is the commonest bostrychid borer in India. It infests dry logs and seasoned timber in depots, sawmills and factories. This species attacks over 75 species of timber. Commonest species of Lyctidae in North India is *Lyctus africanus* Lesne (Fig. 8) which has been widely dispersed throughout India through the agency of infested packing cases, furniture and other wooden articles. Sapwood of more than ninety timber species has been recorded as liable to attack by this species. *Minthea rugicollis* (Walk) (Fig. 9) is the commonest

lyctid borer in Pininsular India and the Andaman Islands. About 32 timber species are susceptible to this species.



Figs. 6. *Xylotrechus smei* Lap. & Gory, in dorsal view. 7. *Sinoxylon anale* Lesne, in dorsal view. 8. *Lyctus africanus* Lesne, in dorsal view. 9. *Minthea rugicollis* (Walk.), in dorsal view.

Stromatium barbatum (Fabr.) (Cerambycidae) is the longhorn borer of seasoned timber. About 350 species of timber have been recorded to be attacked by this species (Sen-Sarma and Thapa 1972). Life-cycle is, in general, completed in one year but may take several years in certain circumstances. The larvae consume starch, cellulose and hemicellulose group (Mishra and Singh 1978).

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ON SOME SYMBIOTIC ASSOCIATIONS BETWEEN DIFFERENT SPECIES OF MARINE ANIMALS

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INTRODUCTION

Certain animals have been known to associate with others since the time of Aristotle. But the study of their relationships and the mechanisms behind these associations, has been started very recently and a great deal remains to be elucidated. The study of relationships between heterospecific organisms, has opened a new field of science, termed as 'Symbiology' or 'the science of symbiosis'

Symbiosis is a broad ecological term used to describe all types of heterospecific associations among organisms, excluding predation, during which there is observed from mere physical contact to absolute physiological dependance of one or all the organisms involved. One of the two or more members of association, is generally larger and in most of the cases, the provider is called the host, and the remaining one or more member associates are termed as symbionts which generally benefit from the relationship.

Our knowledge of marine symbiosis in Indian waters, is very limited. This is largely owing to the fact that the collector interested in one group of animal usually discards the associating partner of another group and vice versa.

The purpose of our present paper is to draw attention to some of our field as well as laboratory observations on the associations of the anemone-hermit crab and the pinnotherid-bivalve species, with a brief review of works in this field. An attempt has also been made to define different types of associations with emphasis on commensalistic associations giving examples from diverse groups.

TYPES OF ASSOCIATIONS

Though there are differences of opinion among the scientists as to define the term symbiosis and other related terms to it, the original sense put forward by De Bary (1879) to mean "living together", is being

retained, and the term parasitism, commensalism, mutualism and phoresis are categorized under it (Cheng, 1967).

Parasitism is described as a heterospecific association either facultative or obligatory, during which the symbiont or the parasite is metabolically dependent on its host. A parasite derives its source of energy from host tissue either by feeding on them or by absorbing from them.

Commensalism can be literally defined as "eating at the same table", during this association, the symbiont or the commensal generally takes physical shelter on or within its host and nourished on food material either sharing with the host or that are associated with the host, but not a part of it. A commensal derives its energy from sources other than host tissue. Inquilinism is a type of association where the symbiont utilizes the host mainly as a refuse and thus shelter and protection are the factors involved, can be included under commensalism.

Mutualism denotes an intimate relationship, when the symbiont or the mutualist and the host are metabolically dependent on each other. Mutual benefit and impossible separate existence are the keynotes.

Phoresis is a kind of loose and non-obligatory type of relationship during which the symbiont is provided with shelter, support and transport by the host organism. Epizoism is categorized separately by some authors, which can be considered under this phoretic association.

Commensalistic Association of Hermit Crab with Anemone and Pea Crab with Bivalve

MATERIALS AND METHODS

The anemone *Sagartia* sp. settled over the hermit crab *Diogenes custos* (Fabricius) was collected from the mouth of Hooghly river. Two species of pea crabs *Pinnotheres cardii* Burger (Fig. B) and *P. boninensis* Stimson (Fig. A) were also collected from the same locality in association with two species of bivalves *Meretrix casta* Gamelin and *Scapharea inaequivalves* (Bruguere) respectively. All these forms were kept alive in the laboratory aquarium for observation. Anemones were removed from their host shell and allowed to settle on the bottom and side wall of glass aquarium. Pea crabs were removed after 7 days by dissecting the bivalves and observed for another week, when the crabs were found dead.

Three examples of the anemone *Adamsia palliata* Bodadsch collected in association with the hermit crab *Dardanus varipes* (Heller), from

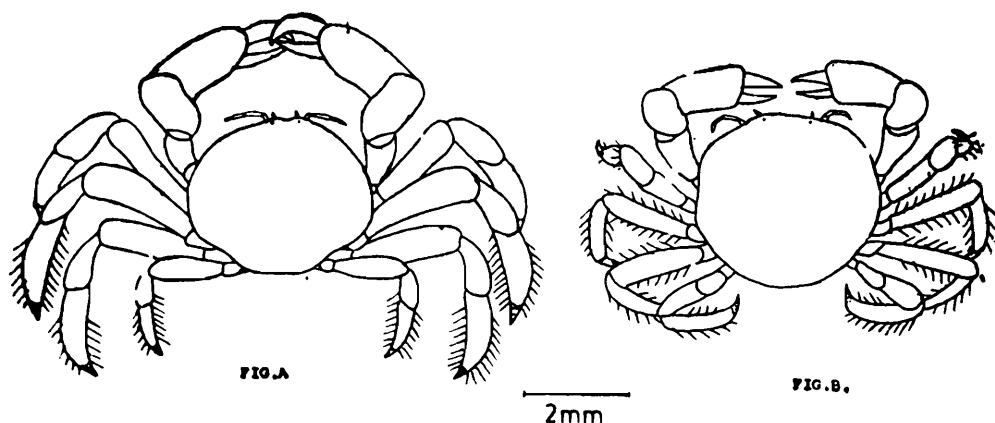


Fig. A. *Pinnotheres boninensis* Stimpson, B. *Pinnotheres cardii* Burger

Cachha island, Mayabandar, Andaman, were identified from the unnamed collection of Zoological Survey of India.

OBSERVATIONS

In The Field

It is observed that the larger mussels which occur in the low-littoral zone that remains submerged for maximum duration, are generally infested with pea crabs. Anemones in association with hermit crabs were collected in large numbers from fishermen's catch. It indicates that they prefer the sub-littoral zone. Rarely observed specimens in the inter-tidal zone are the washed out forms from their natural habitat, due to tidal wave action.

In The Laboratory

Hermit Crab-anemone species-pair

Crabs were found to move towards the anemone settled on the bottom and began to tap and poke the base and the column of the anemone with their walking legs. At first the anemone contracted but later expanded. On the next day, two anemones out of the five, were found to be resettled over the shell of the crab. Other three specimens on the side wall of the aquarium, were not activated by the crab. Unfortunately, further observation was not possible, because a few examples of the gastropod *Salinator fragilis* (Lamarck) (Kept for

developmental study) were found to feed on the isolated anemones. During this encounter, the anemones stung and killed the gastropods. Later, the anemones were also found dead. These poisonous anemones were practically harmless to their hermit crab partners.

Bivalve-pea crab species-pair

Five examples of the bivalve *Meretrix casta* and five examples of the bivalve *Scapharea inaequivalves*, were observed for 7 days, during which no pea crabs found to escape from them. Then the host specimens were dissected and two examples of *Pinnotheres cardii* (♀) and one example of *P. boninensis* (♂) in hard shell stage, were taken out from the mantle cavity of *M. casta* and *S. inaequivalves* respectively. Pea crabs were kept separately to know whether they can carry on an independent existence or not. The females were not able to survive more than three days while the male remained alive upto seven days.

DISCUSSION

Association of sea anemone with hermit crab and pea crab with bivalve, has long been considered as examples of commensalism. Although the acquisition of food due to the host's activities, is the main feature of these associations, other advantages as shelter, transport and provision of a respiratory current (in case of pea crab), may be gained by the commensals. Hence, the commensals find ideal living conditions in being associated with their hosts.

The work of Gosse (1860) is the first of its kind to deal exclusively with some details about the crab-anemone association. Since then, scientists have shown interest in observing carefully the crab-anemone association and studying the ecology of them in the field as well as in the laboratory. The works of Caullery (1952), Dales (1957), Nicol (1960), Ross and his collaborators (1960-1979) are noteworthy. Until now more than 30 species pairs are reported and ecology of some of them has also been studied. Detailed behavioural and ecological studies [Ross (1960-1979), Ross & Sutton, (1961 a, b, 1964 & 1970)] indicate that the association is the result not one of chance but one of choice and by the activity of the anemone or both the partners involved (Table I).

Independent activity of anemone *Calliactis parasitica* (Couch) towards its inactive crab host *Pagurus bernhardus* L., was first observed at the plymouth laboratory (Ross 1960 ; Ross & Sutton, 1961a). It is reported that the contact of the anemon's tentacles with a shell, even an

TABLE I. List of actinians in commensal association with hermit crab.

Sl. No.	SYMBIONT	HOST	Activity in establishing the association.	
			Symbiont	Both
1.	CALLIACTIS PARASITICA	PAGURUS ALATUS	?	
		P. BERNHARDUS	+	
		PAGURISTES OCULATUS		+
		DARDANUS ARROSOR		+
		D. CALLIDUS		+
2.	CALLIACTIS TRICOLOR	DARDANUS VENOSUS		+
		PAGURUS IMPRESSUS		+
		PAGURUS POLLICARIS	+	
		PETROCHIRUS DIOGENES		+
3.	CALLIACTIS POLYPUS	DARDANUS ARROSSOR		+
		D. CRESSIMANUS	+	
		D. DEFORMIS		+
		D. DIOGENES		+
		D. GEMMATUS		+
		D. HAANI	+	
		D. IMPRESSUS		+
4.	CALLIACTIS CONCHICOLA	PAGURISTES PILOSUS	+	
		PAGURUS RUBRICATUS	+	
5.	PARACALLIACTIS JAPONICA	DARDANUS ARROSOR		+
		D. CRESSIMANUS	?	
		D. DIOGENES		+
		D. IMPRESSUS		+
6.	PARACALLIACTIS ROSEA	PAGURUS RUBRICATUS	+	
7.	SAGARTIA (ADAMSIA ?) PAGURI	DIOGENES EDWARDSI		+
8.	SAGARTIOMORPHE SP. (HAWAII)	DARDANUS GEMMATUS		+
9.	SAGARTIOMORPHE SP. (PUERTO RICO)	DARDANUS VENOSUS		+
10.	ADAMSIA PALLIATA	DARDANUS VARIPES		?
		PAGURUS PRIDEAUXI		+

Sl. No.	SYMBIONT	HOST	Activity in establishing the association.	
			Symbiont	both
11.	Unidentified			
	ANEMONE	DARDANUS ARROSOR		+
	"A" (JAPAN)	D. DIOGENES		+
		D. IMPRESSUS		+
		DIOGENES EDWARDSII		+
12.	Unidentified			
	NEEMONE	DARDANUS ARROSOR		+
	"B" (JAPAN)	D. DEFORMIS		+
		D. EDWARDSI		+
		D. IMPRESSUS		+
		D. HAANI		+
13.	SAGARTIA SP.	DIOGENES CUSTOS		?

unoccupied shell or a living gastropod, releases a series of behaviour pattern ; (1) tentacular adhesion ; (2) twisting and stretching of the column ; (3) freeing and lifting of the pedal disc ; (4) arching and somersaulting to the shell ; (5) sticking and spreading the pedal disc on the shell ; (6) release of the tentacles and (7) straightening of the column. This independent transfer of anemone is triggered by a substance of molluscan origin contained in the shells and periostracum (Ross & Sutton, 1961). But recently it is observed that some *P. bernhardus* are not indifferent to *calliactis* (Ross, 1979). The tapping and poking the column of the anemone with the chelipeds and anterior walking legs of the crab, activates the anemones' typical behaviour pattern.

Majority of the crabs living in association with anemones, particularly of *Dardanus* spp. participates actively in the transfer of *Calliactis* to its shells (Burnelli, 1960 ; Faurot, 1910 ; Ross & Sutton, 1961b ; Ross, 1970, 1974, Cuttress *et al.*, 1970) but the crabs alone cannot successfully transfer anemones to their shells without some complementary activity of the anemones, e.g. adherence of the shell by the tentacles or pedal disc of the anemone at the final stage.

Cuttress & Ross (1969) reported that the crab *Dardanus venosus* (H. Milne-Edwards) displayed an active behaviour pattern towards the anemone *Calliactis tricolor* (Lesueur) and that anemone also displayed an active behaviour pattern towards shell. The crab generally began its behaviour pattern towards anemone by tapping gently close to the edge of the base. In response to this stimulation, the anemone relaxed and opened up after first retracting and started loosening its pedal disc so

that became free itself or is easily lifted off by the crab. Similar response of the anemone to artificial stimuli by stick and electricity had also been observed (Ross & Sutton, 1968). Faurot (1910) described in detail an obligatory type of commensalism where anemone *Adamsia palliata* is structurally adapted to live as cloak anemone with *Pagurus prideauxi* with its base covering completely the shell and eventually substitutes itself for the shell as housing for the crab's abdomen. The position of the anemone with its mouth opening just ventral and posterior to that of its host is an ideal position for a food sharing relationship. Fox (1965) reported that the crab on some occasion, deliberately places food among the anemone's tentacles.

Most of the commensal anemone species belong to the genera *Calliactis*, *Paracalliactis* and *Adamsia*, fall under a single family Hormathidae and Hermit Crab species under two genera *Dardanus* and *Pagurus*. The study of zoo-geographical distribution of the crab-anemone association, indicated that they are almost collected everywhere in warmer waters.

Pinnotherid crabs belonging to the genus *Pinnotheres* (Family Pinnotheridae) are well known examples of symbionts associating a varied groups of animal hosts including bivalves, gastropods, tubedwelling polychaetes, holothurians, tunicates etc. More than hundred species of *Pinnotheres* have been reported (Rathbun, 1918 ; Sakai, 1965 and others) and most of them are considered as commensals. The biology of only a few of them is known and the nature of the relationship with their hosts is yet to be studied. At least three species, *P. ostreum* in the American oyster *Cassostrea virginica*, *P. pisum* in the mussel *Mytilus edulis* and *Pinnotheres* sp. in the Indian backwater clam *Meretrix casta* have been reported as parasites (Deon, 1892 Orton, 1920 ; Strauber, 1945 Christensen and McDermoll, 1958 ; Silas and Alagar-swami, 1967). In these cases the symbionts are observed to cause some sort of injury to the host's gill. But the lesions are not caused by the crabs eating on the hosts' tissue. The mantle cavity of the mollusc through which a current of water is always flowing, is an ideal habitat, where refuse, food and oxygen are provided to the symbiont by the host. Moreover, the mantle cavity is naturally bathed in a mixture of sea water and plasma termed "shell liquor", a source of proteins and amino acids to certain symbiotic organisms (Cheng, 1967). Orton (1920) observed the crab's feeding behaviour through "windows" cut in the oyster's valves and reported that the crab obtains their food by eating some of the mucus strings from the gill margins by means of which the

mussel carries its food to its mouth. During this act of feeding the crab may injure their host mechanically. If metabolic dependency concept of parasitism is to be believed, detailed physiological studies on *Pinnotheres* are required before establishing them as parasites. The stomach of *P. pisum* has been found to contain diatoms and other food items of the host (White, 1937). Filter feeding is also likely to occur in some species living in the excurrent region of the atrial cavity of tunicates, in pre-invasive and in earlier post-invasive stages. The feeding behaviour at different stages, is likely to restrict the number of crabs in a host, as they have to depend on the amount of water (mixed with food) pumped into the host. This may account for the absence of crabs in bivalves inhabiting the mid-and upper-littoral zones (authors' observation).

In the pea crabs, males and females are rarely found together within a single host. So, for the purpose of mating there is some provision. Owing to their small size, the males are able to migrate from host to host in search of gravid females. Females unable to migrate from host to host, due to their relatively larger body size, proved advantageous for the very existence of the species. After mating, it is of more importance to the species that the females have the advantage of a good shelter.

Some crabs have been associated with their hosts so long that they have taken some structural modification which make them better adapted to their environment in which they live. Among the Indian species *P. placunae* living inside the greatly flattened oyster *placuna placenta*, has dorso-ventrally flattened body with a more or less squarish carapace.

The complete life history of only two species of *Pinnotheres* namely *P. ostreum* and *P. pisum* is known. It is reported that at a certain stage of its life cycle, *P. pisum* changes its host (Christensen, 1958). After several planktonic zoeal instars, the crabs invades the bivalve *Spisula solida* and after some time, it leaves this host and seeks another host species to complete its development.

To know the host-commensal relationship, the knowledge of all the developmental stages, is essential. Altogether 15 species of *Pinnotheres* have been reported from Indian waters (Table II). The knowledge about the biology of these species, is scanty, (Alcock, 1900, Chhappgar, 1957, 1958 ; Chopra, 1931 ; Hornell and Southwell ; 1909 ; Southwell, 1910 ; Jones. 1950 ; Jones and Mahadevan, 1967 ; Silas and Alagar-swami, 1967 & Misra and Ghatak, 1979).

TABLE II. List of the Species under *Pinnotheres* reported from Indian Water as symbiont.

Sl. No.	SYMBIONT	HOST	DISTRIBUTION (on Indian waters only)
1.	PINNOTHERES ABYSSIOCOLA	LIMA INDICA	Travancore coast
2.	P. BONIENSIS	SCAPHAREA INACOUIVALVES	Mouth of river Hooghly
3.	P. BORRADAILEI	PINNA Sp.	Minicoy Island, Laccadive Archipelago
4.	P. CARDII	MACTRA LUZONICA MERETRIX CASTA	Mouth of the river Hooghly
5.	P. DECCANENSIS	HOLOTHURIA SCABRA	Coast of Madras presi- dency
6.	P. MACTRICOLUS	MACTRA VIOLACEA	Mouth of the river Hooghly
7.	P. PLACUNAE	PLACUNA PLACENTA	Gulf of Kutch
8.	P. PURPUREUS	OSTREA Sp.	Andaman Islands
9.	P. RIDGEWAYI	PINNA ACQUILLATERA	Pamban Is., Gulf of Mannar.
10.	P. SANGUINOLARIAE	SANGUINOLARIA DIPHOS	Travancore coast
11.	P. SETNAI	Unidentified Holothurian.	Port Blair, Andaman
12.	P. VICAJII	PAPHIA MALABARICA	Bombay
13.	P. VILLOSISSIMUS	Holothurians	Andaman Islands
14.	PINNOTHERES Sp.	OSTREA CUCULLATA	Bombay
15.	PINNOTHERES Sp.	MYTILUS Sp.	Trivandrum to cape comorin, Gulf of Mannar
16.	PINNOTHERES Sp.	MERETRIX CASTA	Malpe, North of Mangalore
17.	P. GRACILIS	SOLEN sp. KATELYSIA OPIMA	Karwar coast
18.	P. MODIOLICOLUS	MODIOLA PHILIPPI- NARUM MACTRA VIOLACEA KATELYSIA OPIMA	Karwar & Kodibag

Physiology of Commensalism with Special Reference to Sea Anemone and Pea Crab

Recently emphasis placed on studies relating to the physiology of commensalism, specially the controlling factors behind the host-commensal relationship and the typical behavioural pattern in such association. The works of Caullery (1952), Dale (1957), Davenport (1950, 1953a, 1953b, 1955), Davenport *et al.*, (1951, 1960), Mansueti (1955), Ross (1967, 1973, 1974), Ross and Sutton (1961, 1970). Sastry and Menzel (1962) and others are most important.

In a series of papers Davenport and his Co-workers and Ross with his collaborators have tried to demonstrate whether any chemical factors playing a major part in host-commensal association. Studies by Ross and Sutton (1961a, 1961b) have shown that there is a factor, the shell factor associated with the periostacum of the shell, the nature of which has never been identified but they are evidently stable component of the shell. Experiment on *C. parasitica* and *D. arrosor* showed that when the shell has been cleaned with alkali or coated with plastic, the anemone does not respond with typical behavioural patterns. The behaviour of the crab stimulates a basic motor mechanism of the anemone, producing at first a total general inhibition which is followed by a local contraction at the base that allowed the anemone to be transferred from one substratum to another (Ross and Sutton, 1968). This behaviour pattern of the anemone is based on certain physiological properties of its neuromuscular equipment, that is shown by the fact that the electrical stimuli at low frequency or any other mechanical stimuli, cause retraction then relaxation and detachment (Ross and Sutton, 1970). The work of Davenport *et al.* (1961) on the tentacular nematocyst activity during attachment to the sell, has revealed that the discharge thresholds is lower in free animals than in attached animals.

In obligatory commensalistic association between *P. prideauxi* and *Adamsia palliata*, the crab is immune to the toxins of the anemone, though these are fatal to other organisms. These anemone may have attempted a similar association with other crabs, ultimately finding that only *P. prideauxi* possessed the necessary physiological qualification in the shape of suitable antibodies (Gotto, 1970).

But nothing is known about the factors which attract the pinnotherid crabs to their hosts. But this is very significant as the crab enters its host during the invasive stage, changes its host during growth and

mating (male only). Johnson (1952) has demonstrated by the use of Y-tube choice apparatus that water from an aquarium containing the host sand dollar *Mellitia* sp. has a strong attraction for the crab *Dissodactylus* sp. But the specific factor attracting the commensals is not known. He failed to demonstrate any such attraction in cases of two other commensal pea crabs towards their host polychaete *Chaetopterus* sp. and oyster *Ostrea* sp. *P. maculatus* is capable of recognising its hosts under experimental condition (Sastry and Menzel, 1962). According to them some unknown attractant from the soft part of host is responsible for the active movement of the crab. This is proved experimentally that the crab showed no attraction towards empty shells of their host.

Types of Commensalism

In its strict sense, the term commensalism signifies that only one member of the pair benefits from the association. Nevertheless, there are certain cases particularly in the marine habitat, where both the partners are presumed to be benefited, are loosely termed as commensalism. An attempt has been made to categorize different cases of commensalism into certain groups, though it is a difficult task.

(1) *Feeding independently of the host*

Symbionts is provided with a shelter, and feeding bears little relation to the activities of the host. The female coral gall crab *Hapalocarcinus* lives within a gall produced inside a branching coral. The crab keeps the communication with the outside world by a series of small apertures through which water is always circulating and bringing minute food organisms for the crab. Porcelain crabs of the genus *Porcellanella* are always commensals on sea fans. Almost any organisms exposing to flowing water could serve as a host for this type of association.

(2) *Sharing the host's food*

(i) *Current producing host*

A number of organisms have some mechanisms for sending a water current through their body cavity, such as sponges, bivalves, holothurians and ascidians. Symbionts are not only satisfied by nutritional and respiratory needs, but in many cases guided during their invasive phases to proper host. Shrimps of the genus *Synalpheus* are recorded in large numbers (16,000) from a single loggerhead sponge *Speciospongia vesper* in the Tortugas. Young stages of the stenopid

shrimp *Spongicola* enter into its host sponge *Euplectella*, to live in pairs in their water passages. When they grow, escape is no longer possible.

(ii) *Ciliary-mucoid feeding host*

Animals that create a temporary mucus funnel which traps food particles in the inhalant current. When the funnel becomes clogged, it is promptly swallowed and a new one constructed. The mud-dwelling echiurus *Annalatorhynchus branchyrorhynchus* form a U-shaped tube, available in large numbers on the coast of Sagar island, West Bengal, India. Within its tube a pea-crab, a scale worm and a few isopods and occasionally a gobiid fish are commonly found as commensals (A. Chowdhury & A. Das, unpublished). The peacrabs *Pinnotheres pisum* and *P. ostreum* have shown to feed on the mucus chain produced by their bivalves host.

(iii) *Other groups*

The polychaete worm *Nereis fucata* and various species of hermit crabs are associating together, and their food sharing habit has been studied in some detail (Caulleery, 1952). It has been observed that when the hermit is feeding, the worm glides forward and steals some portion of food from the crab's mandible. Crinoids of the family Comatulidae harbouring a large number of commensals whereas other families of crinoids do not have. One of the reasons for this may be that the formers are not able to close off their ambulacral grooves, providing sufficient food available to commensals (Potts, 1915). While the laterals have plates to close off the ambulacral grooves (Hyman, 1955).

(3) *Feeding on host associated material*

Many of the decapods present on branching coral feed on silt containing mucus shed by the host (Patton, 1960). The mysid *Heteromysis actiniae* feeds actively on the material ejected by its anemone host (Clarke, 1955). The crab *Quardrella nitida* which eats the polychaetes and ophiuroids associated its host gorgonian *Muricea misca*.

(4) *Mutual benefit*

The relationship between hermit crabs and certain anemones is so closed that in case of changing its shell, the crab removes the anemone and places on its new shell. Anemone is benefited by getting a shelter, being transported and sharing the food organisms caught by the crab. On the other hand crab is benefited by getting some protection from predator. Certain crab *Lybia tessellata* utilizes anemones belonging to

the genera *Bunodeopsis*, *Sagartia*, *Phellia*, not only for defence, being thrust forward aggressively if the crab is disturbed, but also as food catchers.

CONCLUSION

A thorough understanding of the relationship between symbionts and their hosts can answer various questions fundamental to biology, particularly, the nutritional requirements of symbionts and their source, the factors involved in attracting the symbionts during invasive phase towards their hosts, etc. Careful observation in the field will reveal many new and interesting associations and the problems relating to them.

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ASSOCIATION OF TRYPANORHYNCH CESTODE PARASITES
WITH VARIOUS TELEOST AND ELASMOBRANCH FISHES
VISITING HOOGHLY ESTUARY OF LOWER WEST BENGAL

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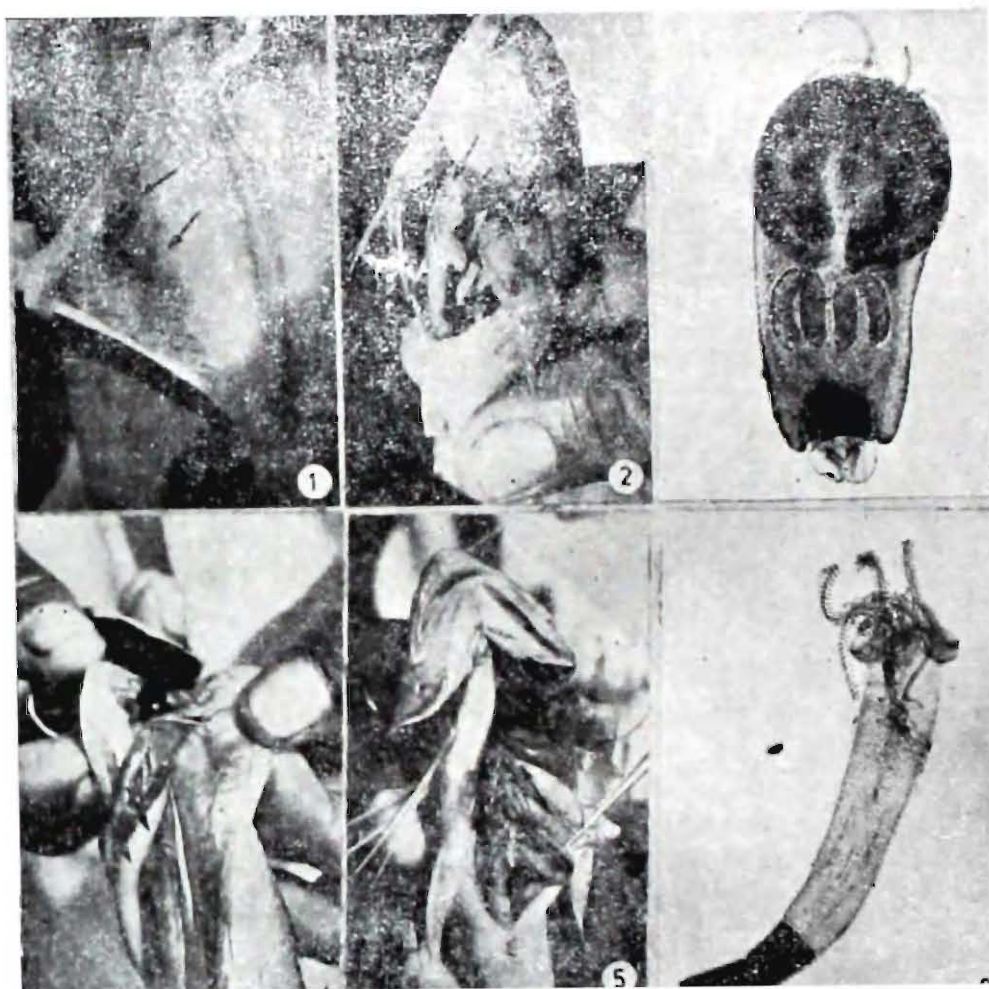
Until recently the spiny proboscide cestode, the 'Trypanorhyncha' from coastal waters of West Bengal were virtually unknown. Ganapati and Rao (1955), Rao (1957), Subhapradha (1951, 1955) and Tandon (1974) reported on the occurrence of some larval and adult trypanorhynchan parasites in some marine teleost and elasmobranch fishes from the Southern coast of India. In the different stages of their life cycle, this particular group of cestode parasites showed the peculiar niche preference in different host species. This paper is the first report of the trypanorhynchs from some commercially important bony and cartilaginous fishes of coastal waters of West Bengal. Among the teleost fishes ; *Harpodon nehereus*, *Polynemus paradiseus*, *Lepturacanthus savala* and *Johnieops menoni* were identified as second intermediate hosts for the larval forms and for the adult worms, the elasmobranch fishes like *Rhinobatus granulatus*, *Dasyatis pastinacus*, *Gymnura poecilura* were encountered as final hosts.

MATERIAL and METHODS

The infected bony and cartilaginous fishes were collected from the mouth of Hooghly river near Sagar Island during the winter months, October to February, of the last three successive years (1977-1980) to investigate the occurrence of the parasites. All hosts were either alive or just dead when captured. The cestodes from different organ locales of the fishes were collected and were fixed under slight pressure or by immersing into aceto-formal-alcohol (AFA). The host species were fixed and preserved in 5% formaldehyde solution. Larval and adult Cestode parasites were stained in semichon's carmine and mounted in Canada balsam. Micro and macro photographs were taken with the aid of Asahi Pentax Camera.

OBSERVATIONS

Among the adult worms, *Eutetrarhynchus* sp., *Hornelliella annandalei* (Hornell, 1912), *Prochristianella* sp., *Pterobothrium* sp., were found to prefer the spiral valves of the elasmobranchs as their habitats. The larval cestodes are mostly found in capsulated condition in different organelle



Figs. 1. Capsulated larval forms in the muscle tissue of *Harpodon nehereus*. 2. Capsulated larva in the peritoneal cavity of *Johnieops menoni*. 3. Larval form of *Nybelinia* sp. 4. Larvae of *Nybelinia* sp. in the peritoneal cavity of Ribbon fish, (*Lepturacanthus savala*.) 5. Showing the larva of *Nybelinia* sp. in the pharyngeal muscle tissue of *Polynemus paradiseus*. 6. Adult form of Trypanorhynch cestode parasite.

of different teleost fishes. Some capsulated larval forms are found in the muscle tissues of *Harpodon nehereus* (Fig. 1) and *Lepturacanthus savala* and some are identified in the peritoneal cavity of *Johnieops* sp. (Fig. 2). Two different species of the genus *Nybelinia* were recovered in free moving condition along with the capsulated forms. The white

oval *Nybelinia* sp. (Fig. 3) was identified from the gonadal region of the peritoneal cavity of the Ribbon fishes (Fig. 4). In few cases the stomach muscle tissue of Bombay duck (*Harpodon nehereus*) also harboured this parasite. Another species under the same genus was found to prefer the pharyngeal muscle tissues and the pericardial cavity of *Polynemus peradiseus* (Fig. 5).

But it is amazing that the adult worms of the heterogenous trypanorhynchal species show the typical and common niche preference (spiral valves) in the selachian hosts.

Both the adult and larval forms possess mobile holdfast and provided with two or four sessile bothridia and four tentacles. These are armed with rows of hooks of different size and shape and are withdrawn within the holdfast (Fig. 6). By the help of these armatures the parasites anchor in the host tissue.

DISCUSSION

The life cycle of these small tape worms showed the special interest due to their peculiar morphological structure and for their host preference. In their life cycle they enjoy the free environment only once during the shading of the eggs in water with the final host's faeces. Many scientists like Southwell (1929c), Ruzskowski (1932c), Young (1955), and Rae (1958) studied the life history of these parasites. Indian scientists like K. Hanumantha Rao, Ganapati, Tandon, Kambata, Subhapradha and others worked on different aspects of this group of parasites.

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HOST PLANTS AND BIOMORPHOLOGY OF SOME APHIDOIDEA

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INTRODUCTION

Aphids present one of the most interesting biological association with plants as their hosts. Most of the primitive aphids including Adelgids, indicate an old association with conifers, some forming galls on the Coniferous trees (Adelgidae), others feeding on needles (Lachninae), while still others remaining confined to the roots (Pemphiginae : Prociphilina). Present day host association of aphids however exhibits a much wider food preference, spanning over Magnolidae — Hamamelidae — Dilleniidae — Rosidae — Asteridae and Liliatae. From biological point of view, each of the host plant presents an environment congenial to the feeding and reproduction of these insect pests ; even several different paracycles have evolved in the life cycle of Aphidoidea, largely due to absence of one host plant or the other. The present paper would be restricted to the Adelgidae on in side and the Pemphiginae + Hormaphidinae of Aphididae on the others, as these groups would perhaps be indicative of a most intimate biological association with plants, resulting in many cases, formation of closed primary galls or pseudogalls and retention of many unique, primitive morphological and biological characteristics.

ADELGIDAE : CONIFERAE ASSOCIATION

The woody plants, on which, aphids are supposed to have originated present several advantages. The tall coniferous trees, when acting as primary host, in case of heteroecious species often present an ideal foci for formation of galls. Adelgids, considered to be one of the most primitive aphid-groups, are monophagous on Coniferae, their primary host being *Picea* species and secondary hosts belong to *Abies*, *Larix*, *Pinus* and *Tsuga* ; in case of complete cycle, (Holocycle) the galls (Figs. 1-3) are initiated by Fundatrix which emerge from eggs, and these galls may be single chambered or multichambered, and of different

shape, size and variable pubescence ; in case of absence of galls on primary hosts, overwintering is effected by hibernating under the bark of the same host. Biologically, the most interesting feature retained by these aphids is that both parthenogenetic and sexuales forms have oviparous female as opposed to parthenogenetic viviparous females in other aphidoidea. Normally adelgids may have as many as 5 generations, while leading a heteroecious holocycle (fundatrix, gallicola, sistine, sexupara, sexuales) which may become reduced to only two generation (sexupara and sistines) in case of monoecious anholocyclic forms (Annand, 1928). Morphologically (Figs. 4-9). Adelgids show (i) development of wax glands, (ii) reduction of wing venation, (iii) small 3 faceted eyes in apterae, (iv) stylets much longer than rostrum, (v) and absence of siphunculi and cauda besides rostrate sexuales. Many of these (barring rostrate sexuales etc. in Pemphiginae) have much of similarity with other gall-aphids belonging to Aphididae, Pemphiginae and Hormaphidinae.

From ecological view point, the host association specially, the primitive mode of gall-formation resulted in the absence of natural enemies, specially braconid parasites, which are otherwise well distributed in other modern aphid-groups.

PEMPHIGINAE AND HORMAPHIDINAE : ASSOCIATION WITH MAGNOLIDAE—HAMAMELIDAE—DILLENIDAE—ROSIDAE.

Taxonomically, many aphidologists prefer to group these two sub-families into a single coherent family Pemphigidae. The reasons for such lumping are worth investigating. The Pemphiginae have three distinct group of primary hosts (Figs. 10-12) for members of three tribes—Salicaceae (*Populus*) [Pemphigini], Ulmaceae (*Ulmus*) [Eriosomatini] and Anacardiaceae (*Pistacia/Rhus*) [Fordini] ; secondary hosts of Salicaceae infesting Pemphigini belong to Coniferae/Dicots, while for some *Rhus* infesting Fordini (Melaphidina) secondary hosts are Mosses. Biologically, members are heteroecious but sexuales become degenerate with loss of rostrum. The primary host association as such include Hamamelidae (*Ulmus*), Dilleniidae (*Populus*) and Rosidae (*Pistacia/Rhus*). On *Ulmus*, closed galls are formed by *Tetraneura*, *Gobaisha*, *Watabura* and on many of these, fundatrix exhibit completely different morphological characteristics than the apterae from secondary host ; On *Populus*, members of *Pemphigus* and allied genera may form stem gall, or leaf galls, and on *Pistacia* and *Rhus* members of *Forda*, *Aploneura*, *Baizonigia* or *Melaphis*, *Schlechtendalia* produce closed galls

of various shape which only open in the second year and even in a two year cycle, fewer generations are produced.

Hormaphidinae, on the other side, have three tribes, members of two of which remain confined to Hamamelidae as primary host (Figs. 13-14) (Nipponaphidini and Hormaphidini), while the members of third tribe, Cerataphidini use Dilleniaceae (Fig. 15) as primary host ; secondary hosts of Hormaphidini remain confined to Betulaceae of Hamamelidae (reminding us of Adelgids on Coniferae), of Nipponaphidini to Magnoliaceae (Lauraceae) Hamamelidae (Fagaceae/Moraceae) and some on Liliaceae ; secondary hosts of Cerataphidini largely include, Gramineae, Orchidaceae, Arecaceae, Palmae—all under Liliaceae.

The host-plant association and habit of gall formation on primary hosts in many members of Pemphiginae and Hormaphidinae, perhaps could explain the peculiar assemblage of morphological characters (Figs. 16-17) ; viz. (i) development of wax glands, (ii) reduced antennal segments, (iii) reduced eyes in apterae (iv) reduced wing venation and (v) ill developed siphunculi which may even be absent ; life cycle of most primitive Hormaphidinae span over two years, having 6-7 generations, as also the 2 year life cycle of gall forming Fordini in Pemphiginae (but in Fordini, generations are fewer). However, major morphological differences occur between the aleuroidid apterae (on bark, leaves) of Hormaphidinae and subterranean root feeding apterae of Pemphiginae, both groups showing extreme adaptive modifications ; on the other hand, sexuales of primitive Hormaphidini still possess rostrum (as in Adelgids) which become degenerated in Pemphigids. As may be expected, from the data on Adelgidae, Hormaphidinae remain almost free from aphidiid parasites, while Pemphiginae have at least eight parasites.

DISCUSSION

The relationship of three different aphid groups, primarily from their association with host plants and habit of gall-formation indicate a phylogenetic picture, largely dependent on geologic evidence of occurrence of host-plants at particular time and other evidences of plant evolution. Phenology of phytophagous insects is governed by both biotic and abiotic factors of environment and host plant form the most important component, controlling several aspects. Plant systematists believe that Coniferae are more primitive than angiosperms and primitive angiosperms in their turn must have arisen from

a Hamamelid-Dillenid line or along a Laurales-Hamamelid line (Fig. 18). Besides evidences from pollen type, wood anatomy, mode of pollination, data from secondary metabolies also exhibit a chemical pathway—which evolved continuously to repel the insect pest as and when one group of chemical becomes ineffective. As such, it has been thought to be a natural sequence (Fig. 19) of benzyl isoquinoline alkaloids (Magnolidae)—anthocyanin/tanin (Hamamelidae, Dillenidae, Rosidae)—Iridoids (Dillenidae, Rosidae) Polyacetylene (Asteridae) (Cronquist, 1977); sequence of gall forming aphids, likewise, may be drawn placing Adelgids as a distinct branch on Coniferae and Hormaphidinae/Pemphiginae as a separate branch themselves bifurcating at an early stages and confining to Hamamelidae-Dillenidae-Magnolidae or Hamamelidae-Dillenidae-Rosidae lines of Plants.

The effects of abiotic factors, through the plant-pathway or directly on aphids need to be considered in this respect; specially, the distribution of host (so effectively controlling the distribution of these insects) which is governed by climatic factors, altitudes and other temporal factors. They could well be appreciated when present day distribution of Adelgidae (mostly Holarctic), Hormaphidinae (mostly in East & South East Asia) and Pemphiginae (Holarctic, Nearctic, Mediterranean and Oriental) is considered.

The host-plants, as such appears to be the most important component in the environment, regulating life cycle (Fig. 20), polymorphism, morphology, dispersal, distribution and evolution of phytophagous insects like aphids.

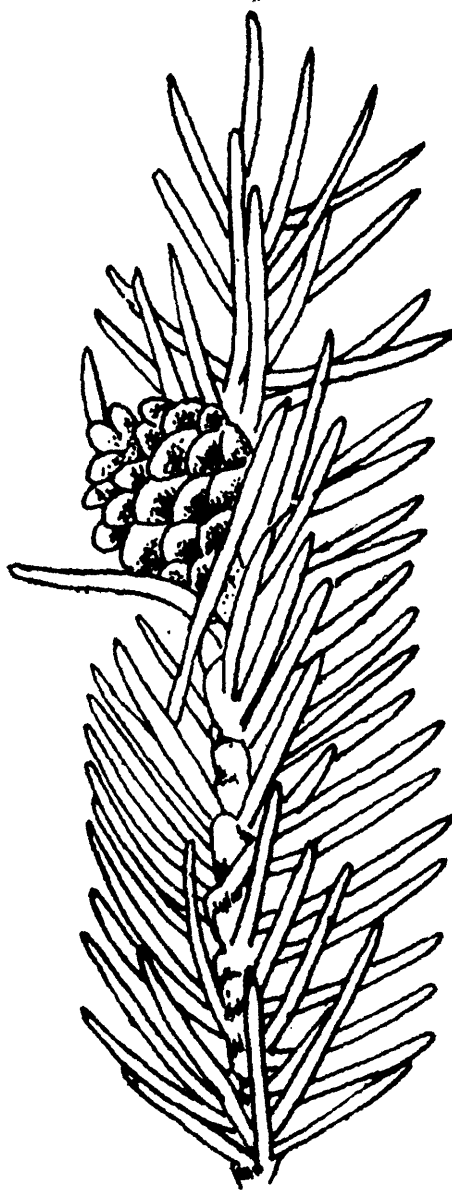


Fig. 1. Adelgidae : Galls on Coniferae.



Fig. 2. Adelgidae : Galls on Coniferae.

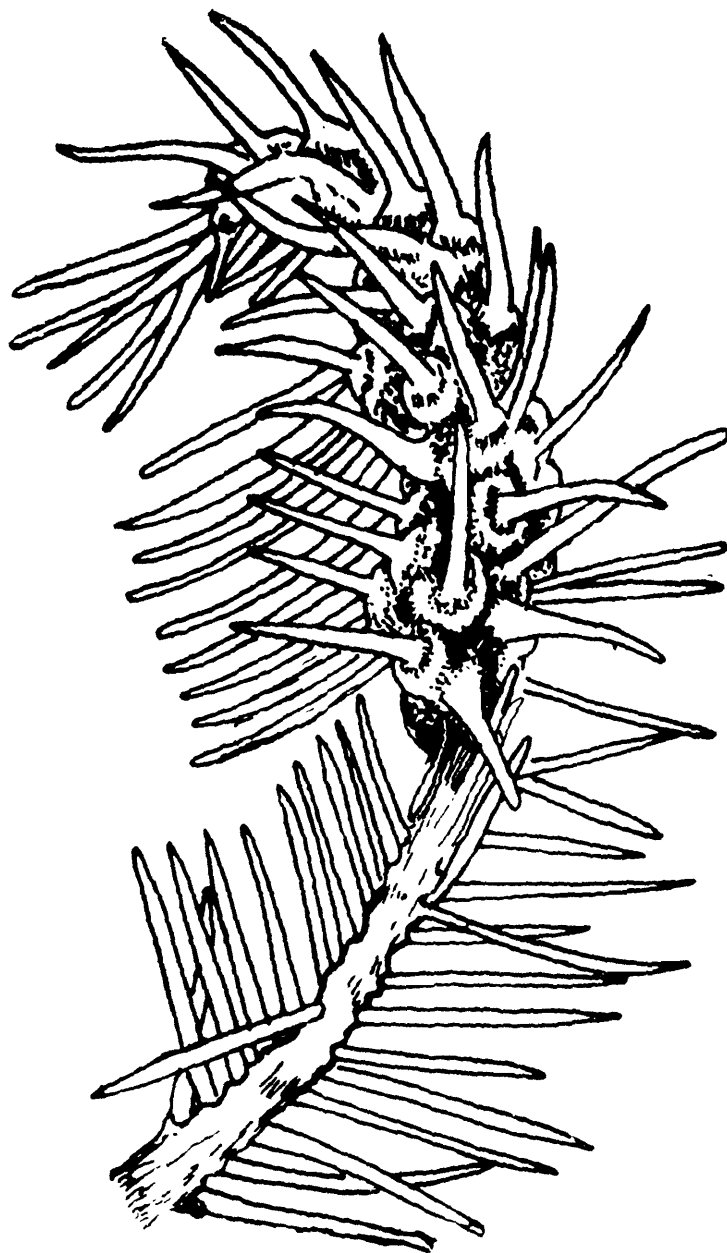


Fig. 3. Adelgidae : Galls on Coniferae.

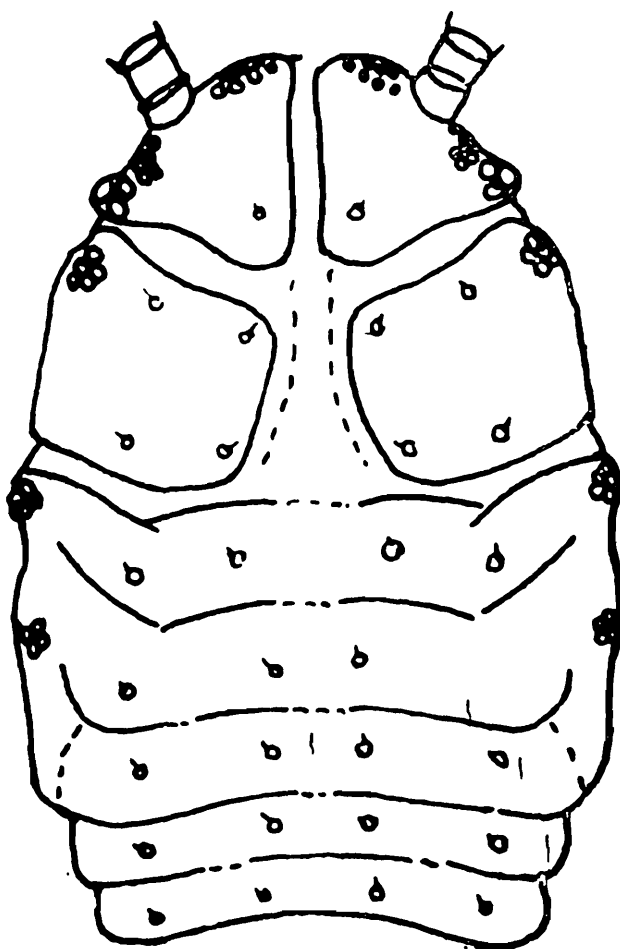


Fig. 4. Adelgidae : First instar nymph of sistine on secondary host.

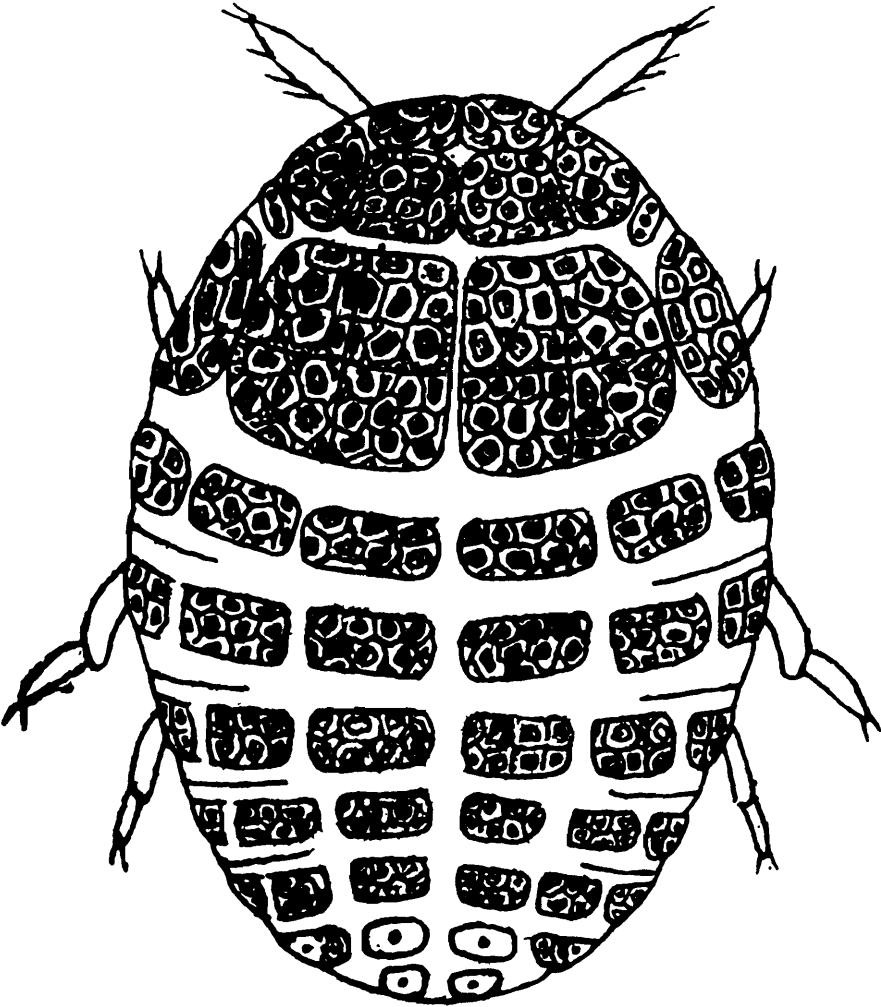
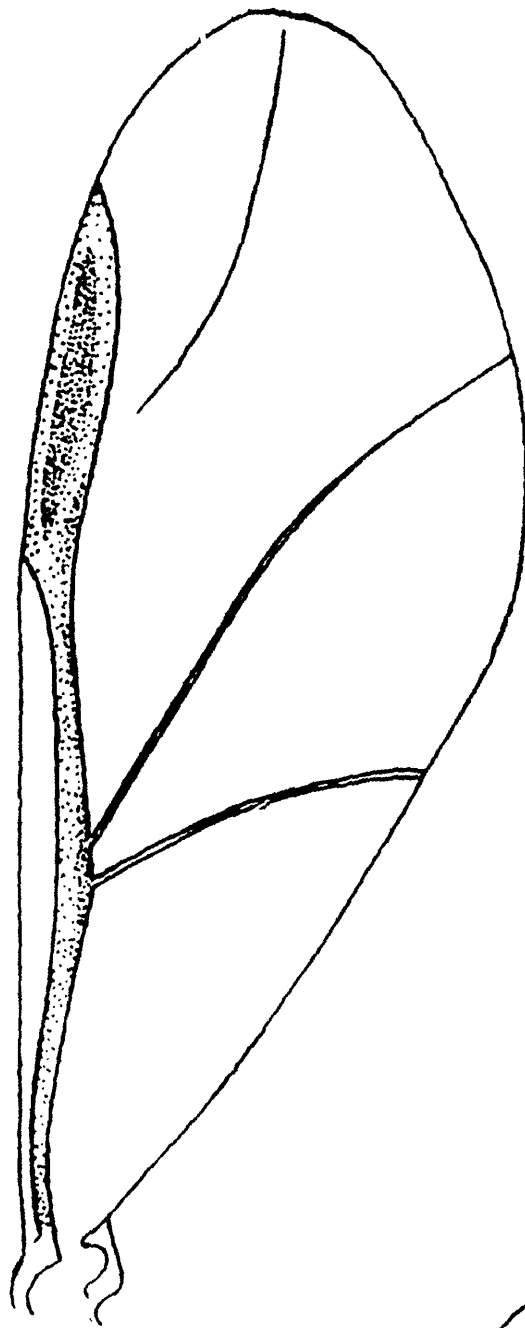
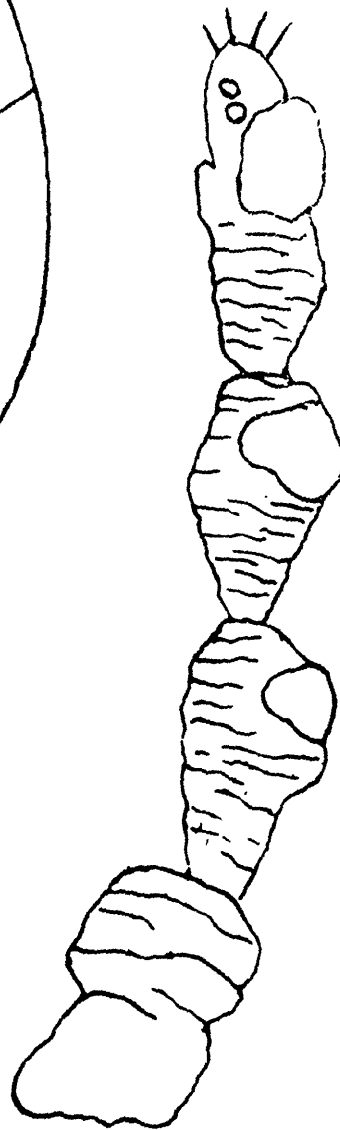


Fig. 5. Adelgidae : First instar nymph of Fundatrix on primary host.



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Figs. 6-7. Adelgidae: 6, Forewing of alate viviparous gallicola. 7, antenna of alate viviparous gallicola.

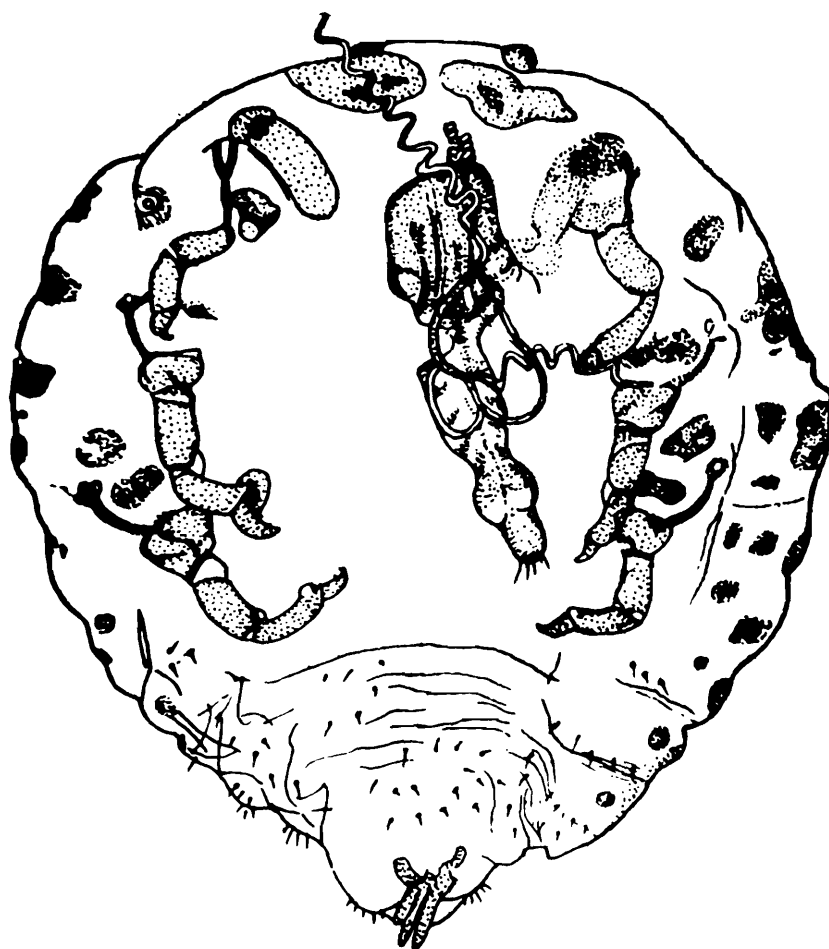


Fig. 8. Adelgidae : apterous viviparous female (sistine), dorsal view.

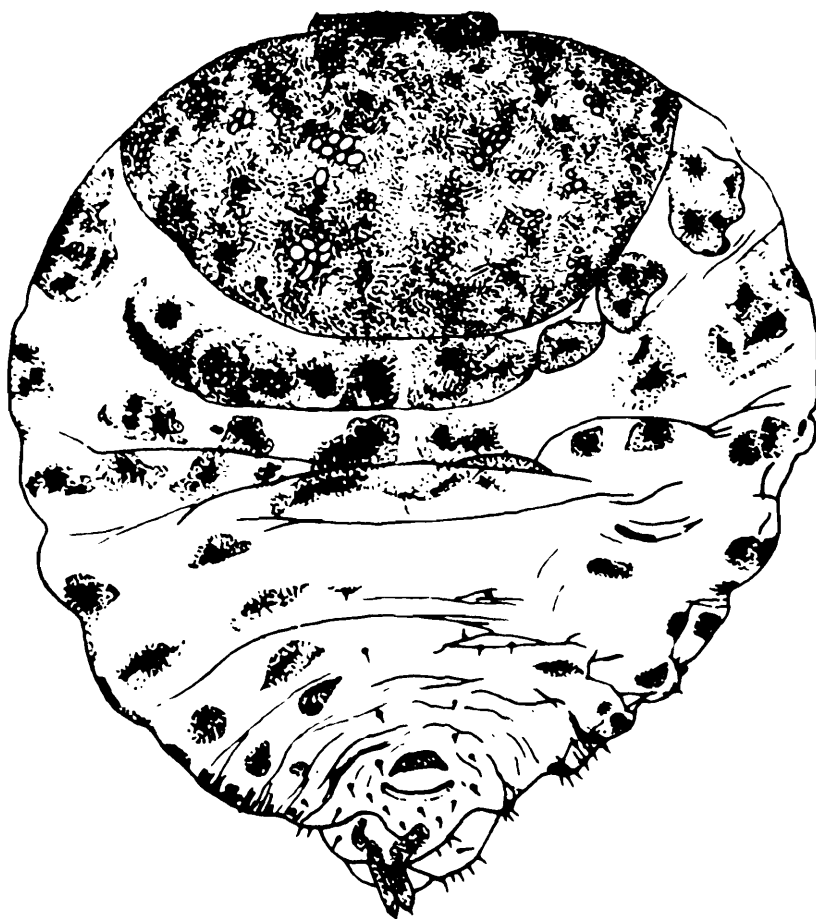
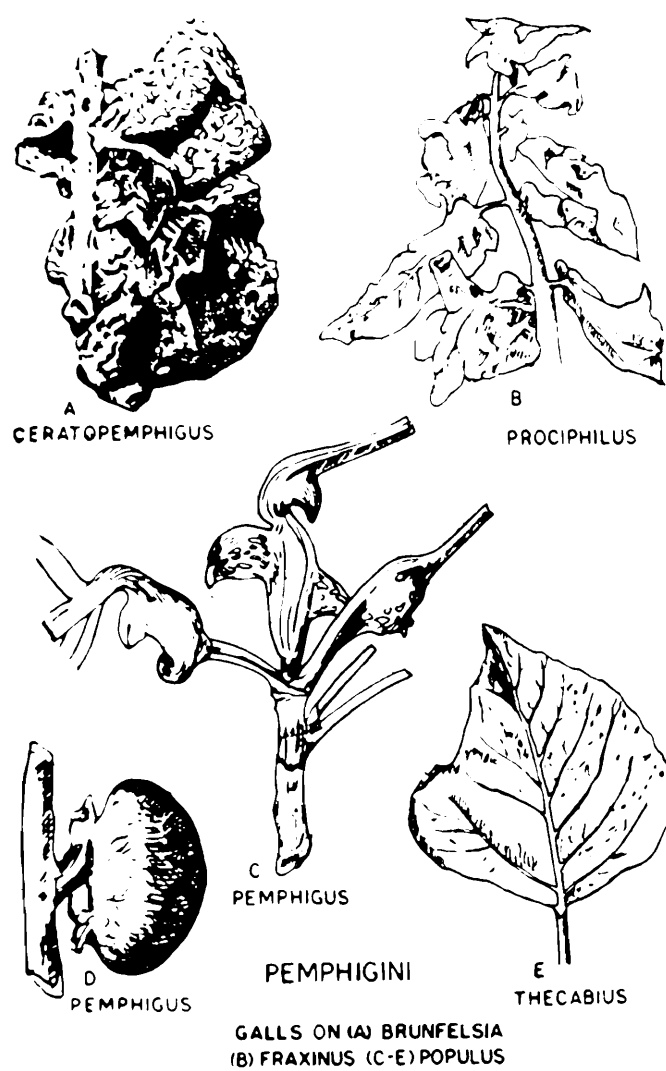


Fig. 9. Adelgidae : apterous viviparous female (sistine), ventral view.



Figs. 10. Pemphiginae : galls on *Burnfelsia*, *Fraxinus*, *Populus*,

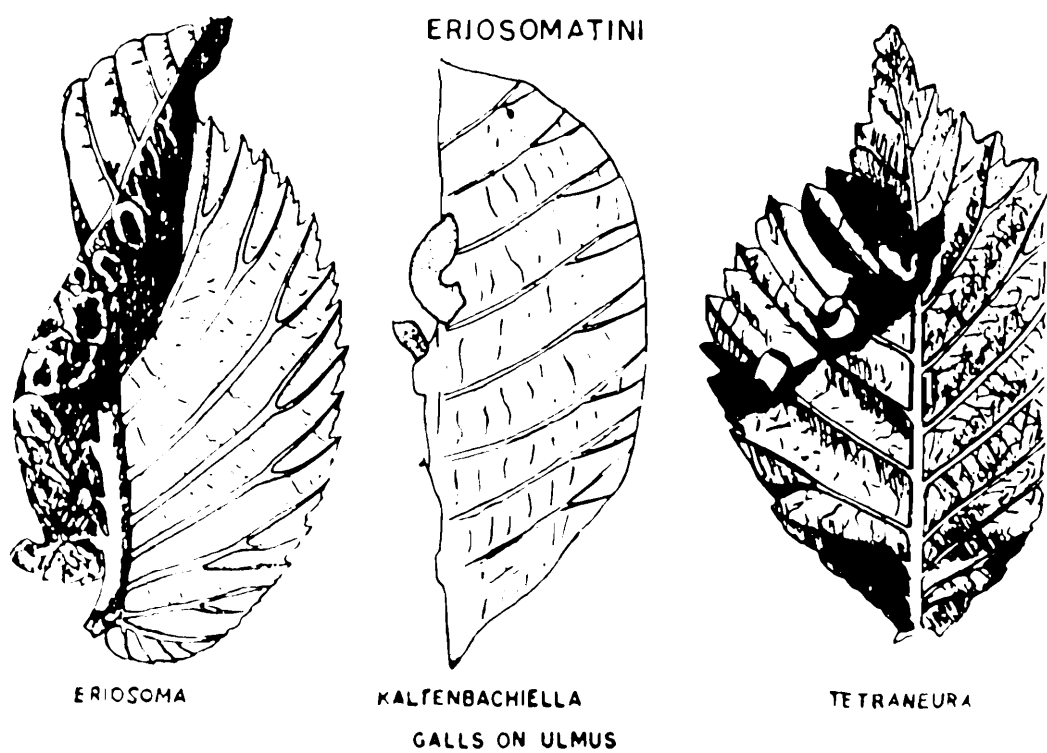


Fig. 11. Pemphiginae : galls on *Ulmus*.

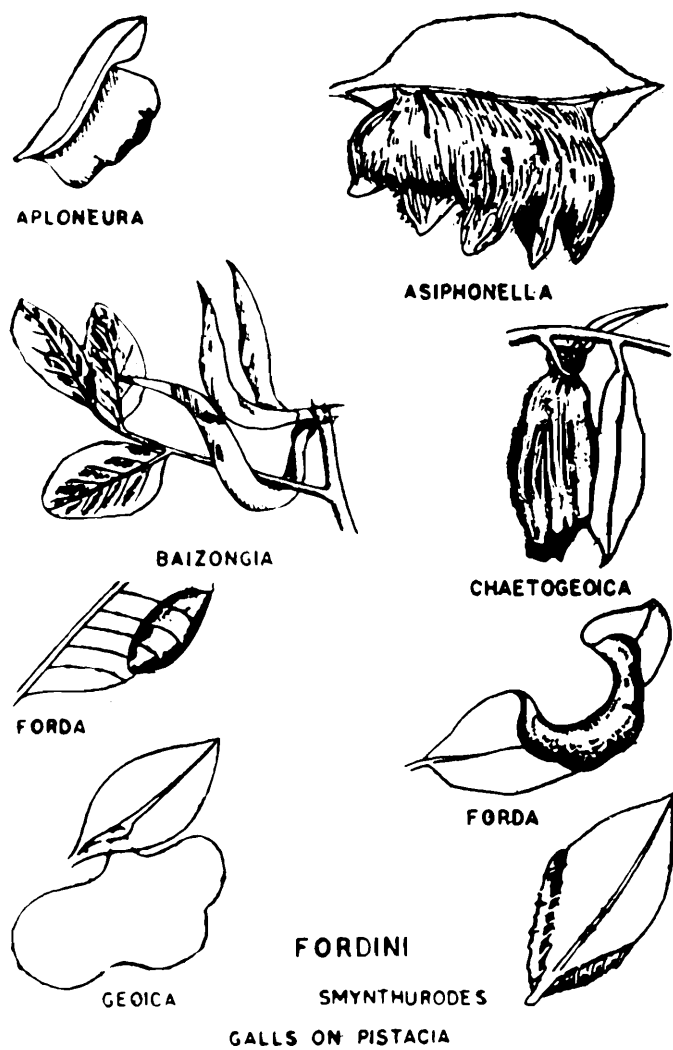
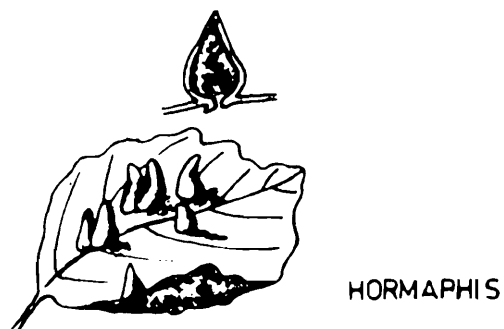


Fig. 12. Pemphiginae : galls on *Pistacia*.



HORMAPHIS



HAMAMELISTES



GALLS ON HAMAMELIS

Fig. 13. Hormaphidinae?: galls on Hamamelis (Hormaphidin)

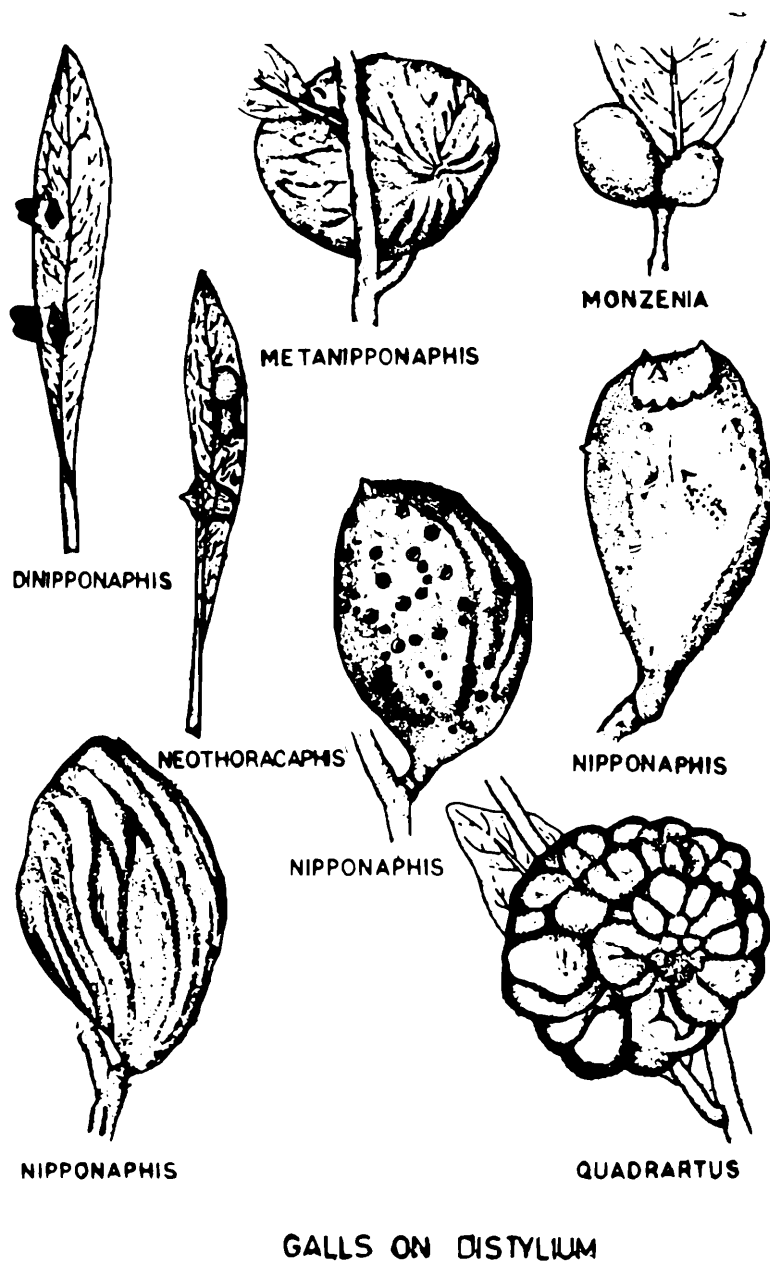
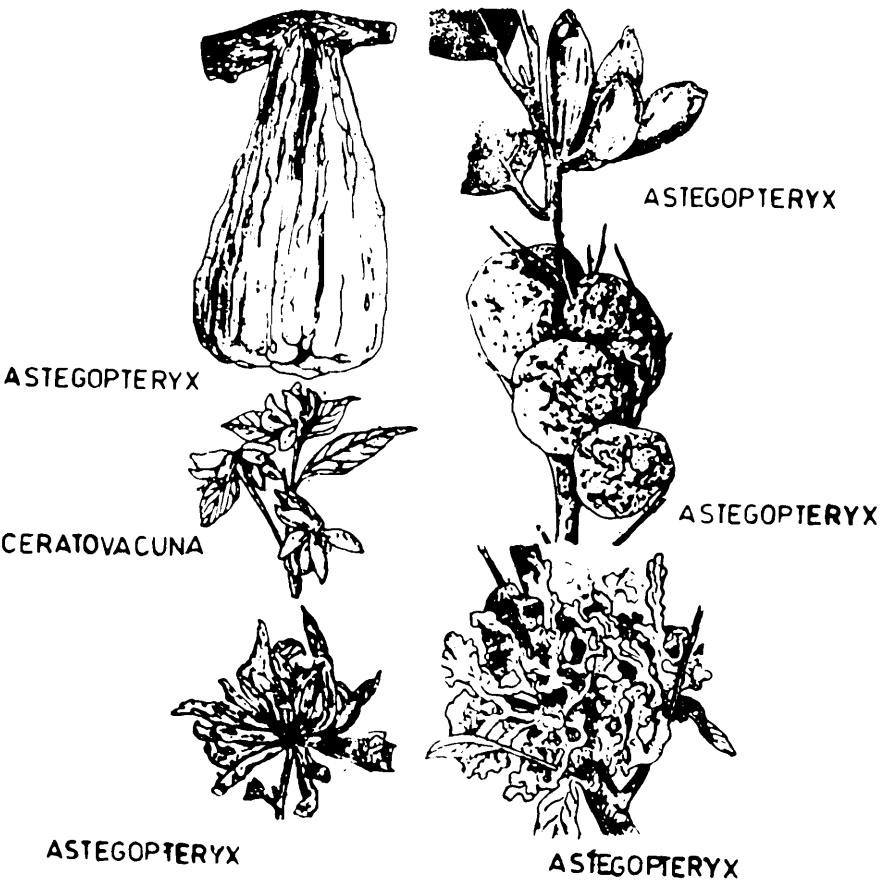
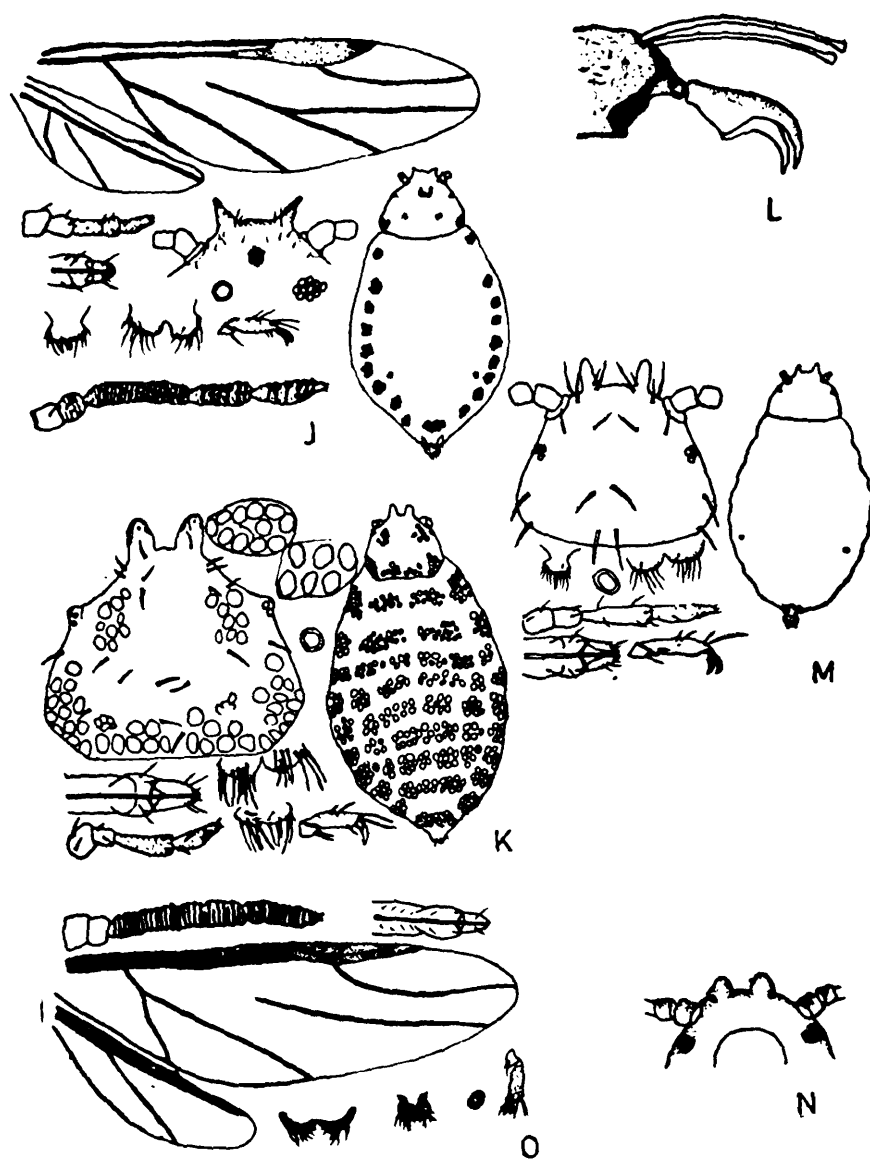


Fig. 14. Hormaphidinae : galls on *Distylium* (Nipponaphidini),



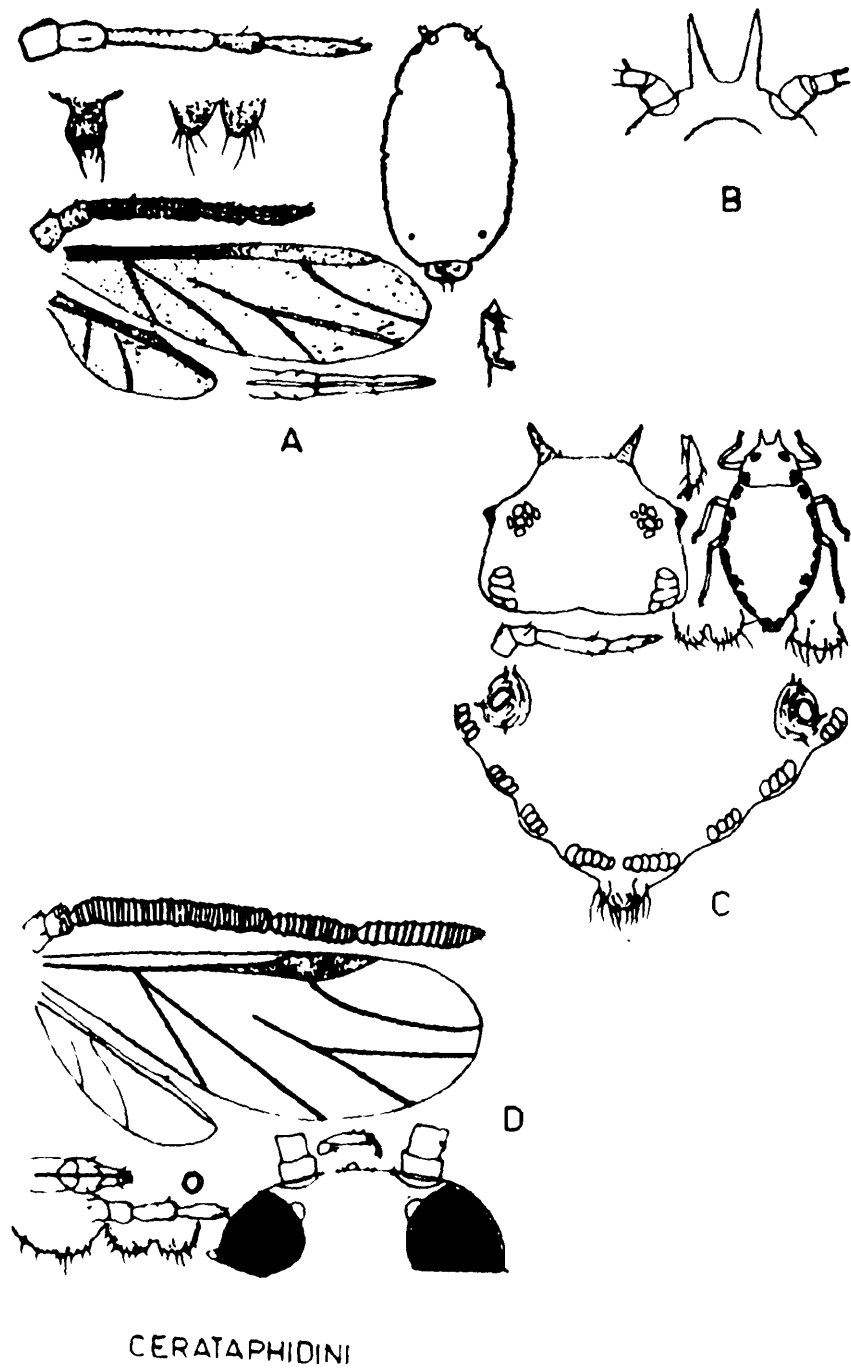
GALLS ON STYRAX

Fig. 15. galls on *Styrax* (Cerataphidini).



CERATAPHIDINI

Figs. 16. Hormaphidinae ; Morphological characters in some genera on primary and secondary hosts.



CERATAPHIDINI

Fig. 17. Hormaphidinae : Morphological characters in some genera on primary and secondary hosts.

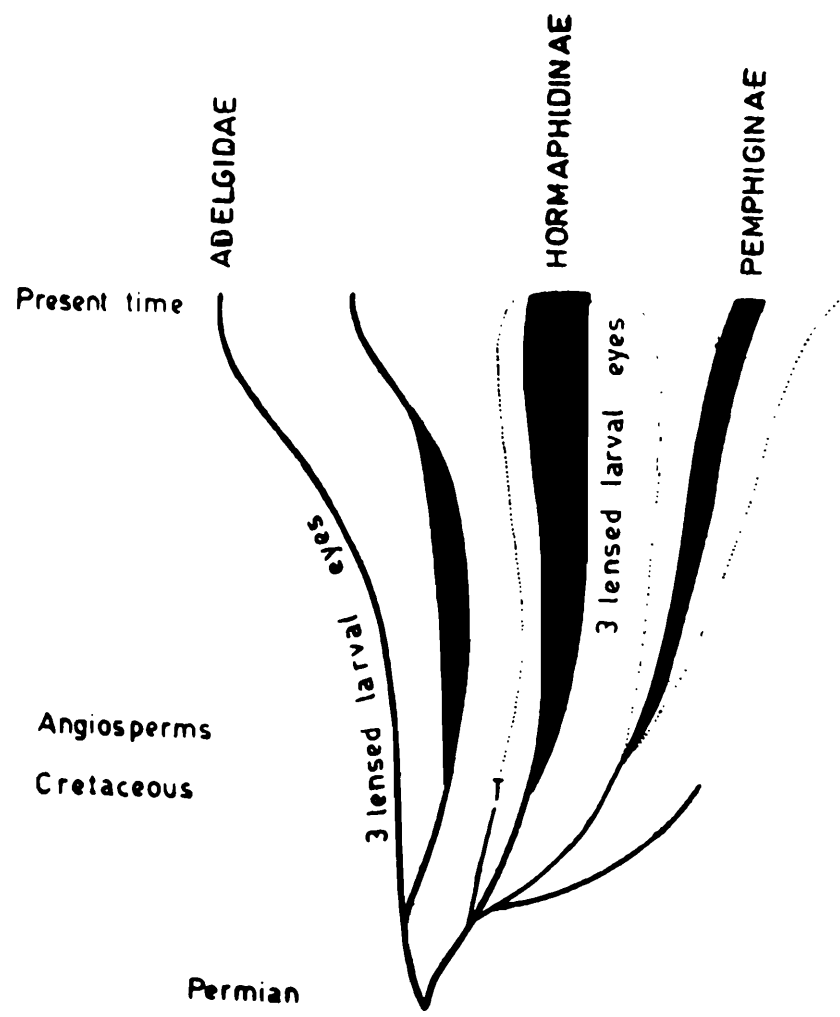
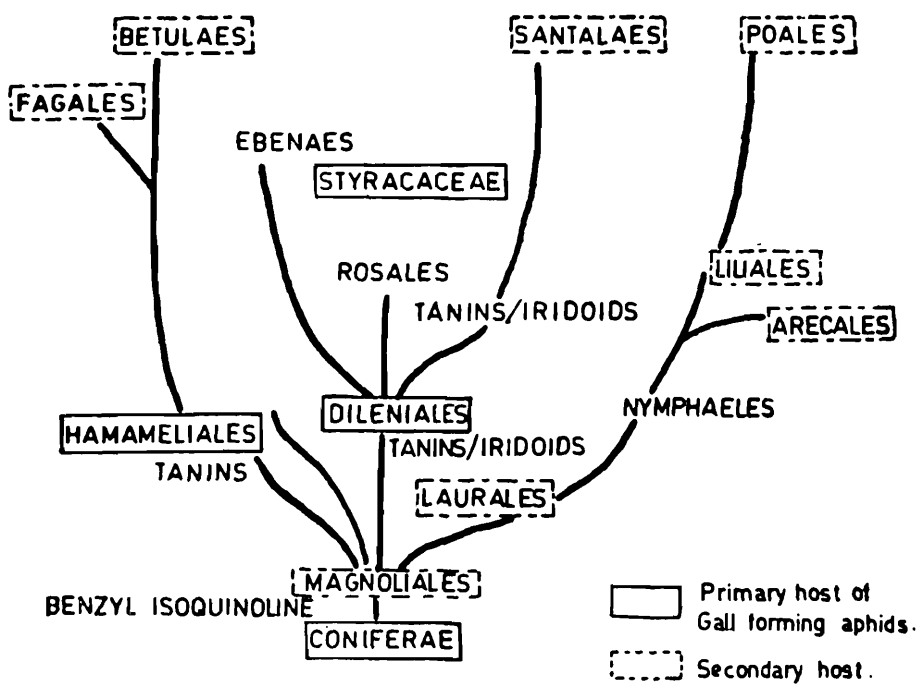
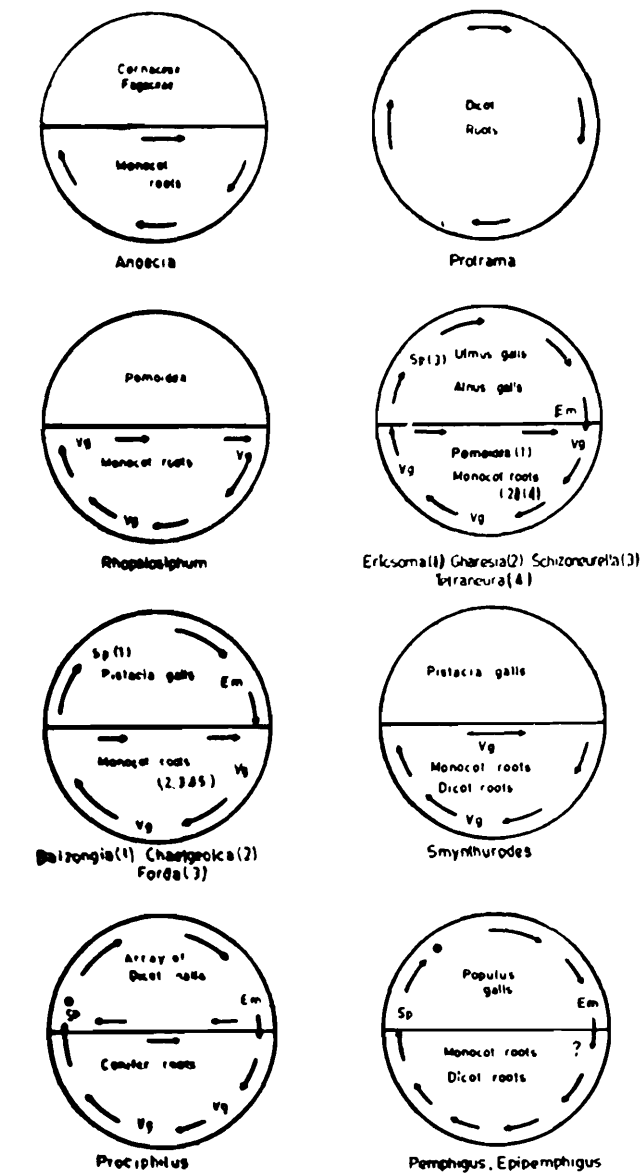


Fig. 18. Parallel evolution of Aphids on Plants.



PHYLOGENY OF ANGIOSPERMS

Fig. 19. Evolution of Angiosperm and gall forming aphids.



BIOLOGY OF SUBTERRANEAN APHIDS

Fig. 20. Paracycle in Aphid-biology due to loss of host-environment.

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ON SOME ASPECTS OF ENVIRONMENTAL MODIFICATION,
AT BIO-CHEMICAL LEVEL IN TOMATO PLANTS
(*LYCOPERSICON ESCULENTUM* MILL.) DUE TO
THE INFESTATION OF *MELOIDOGYNE*
INCOGNITA (NEMATODA).

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INTRODUCTION

The infestation by *Meloidogyne* worms and subsequent gall formation in the root tissues of tomato and other vegetable plants oftenly leads to the enormous increase in protein and aminoacids and decrease in carbohydrates. This fact has been demonstrated by a number of workers, viz. Christie 1936, Mountain 1960, Owens & Specht 1966, Epstein & Cohn 1973, Alam *et al.* 1976, Okopnyi 1976. The accumulations of different plant growth regulators (like indole compound etc.) and amino-acids have been described by a number of authors like Balasubramaniam & Rangaswami 1962, Bird 1962, Honounik & Osborne 1975, Dropkin 1976, Melnik and Bumbu 1976, Gommers and Dropkin 1977. Most of them in some way have related protein and amino-acid accumulation with *Meloidogyne* infestation. But so far none of the work has measured and established the relationship between the degree of infestation and the rate of increase in amount of protein. The present work was taken with a two fold aim, first to establish the regression of protein ratios in relation to the rate of infestation and next to establish and estimate the nature of correlation between the root protein, number of galls and the parasitic population.

1. A Tata-Fison Product.

2. The surface area of a pot was assumed 1 sq. ft. approximately, and the dose of aldrin was considered 5% powder 20 Kg. per hectare against the insects.

Many plant species have been reported to have nematocidal properties ; Ellenby 1951 ; Oostenbrink *et al.* 1958 ; Bhakuni *et al.* 1969 ; Sukul 1970 ; Abivardi 1971 ; Gommers 1972 & 1973 ; Hackney & Dickerson 1973 ; Hackney 1973 ; Khan *et al.* 1974 ; Sukul *et al.* 1974 ; Husain & Masood 1975 ; Egunijobi & Afolami 1975 ; 1976 ; Ueno & Iyatomi 1978. In the present experiment, the test plants with uniform initial infestation were treated with three plant extracts (which were having nematocidal properties namely *Anthocephalus kadamba* (Fam. Rubiaceae) *Tragia involucrata* (Fam. Euphorbiaceae), *Peristrophe bicalyculata* (Fam. Acanthaceae) along with an insecticide aldrin¹. (aldrin=1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4a. 5, 8, 8a-hexahydro-1, 4, endoexo-5, 8-dimethanonaphthalene). Since aldrin is extensively used for controlling soil insects and some times has also been used against nematodes, (Recavarren-Herrera 1976 ; Hafner 1978) this was choiced to see whether this proves also effective against the root-knot nematodes.

MATERIALS AND METHODS

In a pot culture experiment, seventy two 32cm. diam. earthen pots, each containing 2 : 1 (%) mixture of sterilized clay soil and compost manure were taken. Seeds of tomato were surface sterilized and sown ; two in each of seventy two pots. After germination, ultimately only one plant was allowed to grow in each pot. Sixty pots were inoculated with *Meloidogyne incognita* larvae at 800 larvae per pot, when the seeds were sown, and twelve pots served as uninoculated control. The larvae for inoculation were collected by shifting infected soil of the green house pots. The screening so obtained were diluted with water, sampled for determining the population density of *M. incognita*, and then applied as inoculum to the pots at the rate of 100 ml. per pot.

Ten days after inoculation, each twelve pots, inoculated with *M. incognita* larvae, were given 200 ml. of water extract of *A. kadamba*, *P. bicalyculata* and *T. involucrata*. Another batch of twelve inoculated pots were given 0.2 gms. of 5% wettable powder of aldrin per pot². Water decoction of each of three plants were prepared by boiling 1 Kg. of fresh leaves of each category with 2.5 litres of water for 20 min. (Sukul *et al.* 1974). The rest 12 pots served as inoculated untreated control. The test plants were allowed to grow for 60 days, after which they were harvasted together with their roots. Their root wt. root

length, shoot wt. shoot length and number of galls per plant were counted. After the harvest the nematode population, in the rhizosphere of each batch of plants were estimated separately.

The roots of 6 batches of inoculated and uninoculated plants were cut and chopped separately. Then from each of 6 batches of treatments 3 samples were taken at random and the total protein ratio in relation to the total root wt. were estimated separately. The method for protein estimation was followed after Lowry *et al.* 1951. Two correlations were established by calculating the correlation coefficient between the final population (after harvest) and the average gall index numbers, and next, between the gall index numbers and the average ratios of total protein in each treatment.

Soil temperature was $30^{\circ} + 2^{\circ}\text{C}$ during the experiment. Pots were exposed to natural light and rainfall, and were irrigated when necessary.

OBSERVATION

The effect of aqueous extract of *A. kadamba*, *P. bicalyculata*, *T. involucrata* and dilution of aldrin on tomato plants, inoculated with *M. incognita* is presented in table 1. 'F' values and critical differences have been estimated to see whether the differences between the treatments are significant.

No phytotoxic effect was observed with any of the plant extract or aldrin. There has been a marked increase in shoot wt. and shoot length in all types of treated plants over the untreated inoculated plants. The highest development is found in the *A. kadamba* treated plants. The variation in root weight is insignificant between treated and untreated plants. The differences in number of galls and final rhizospheric population is highly significant, even at 0.01 level. Highly significant reduction in the number of small galls and final population are found among all the treated plants, of which *A. kadamba* gave maximum control, which has also been reflected in the protein ratio of the *A. kadamba* treated plants, being the minimum of all treated plants, next to that of uninoculated untreated control. The inoculated untreated plants showed maximum protein content and maximum galling incidences. The correlation between the final population and gall

TABLE 1

TREATMENTS	root in in cms.	root wt. in gms.	shoot in in cms.	shoot wt. in gms.	final popln.	av. no. of galls	av. protein %
Uninoculated control	130.2*	7.5	49.5*	83.5*	0	0	2.15*
Inoculated control	15.0	7.1	29.7	51.5	668.3	146.0	5.10
<i>Anthocephalus</i>	24.5*	8.0	46.9*	76.9*	93.7*	62.5*	3.10*
<i>Tragia</i>	19.7*	7.7	38.0*	71.7*	208.7*	88.4*	3.90*
<i>Peristrophe</i>	22.5*	7.75	3.6*	63.5*	210.8*	69.5*	3.75*
aldrin	17.8	6.8	33.4	56.5	231.2*	98.6*	4.35
'F' value	10.0	1.27	8.72	6.91	226.2	36.02	16.22
critical difference at 5% level	4.66	1.05	7.25	12.0	42.3	22.14	1.17

1. Each number is average of 12 replicates

* The difference of the figures with *marks are statistically significant at 5% level when compared with inoculated control.

index number has been presented in figure 1 and the correlation between gall index number and protein ratio presented in figure 2. The correlation in both the cases are positive and highly significant.

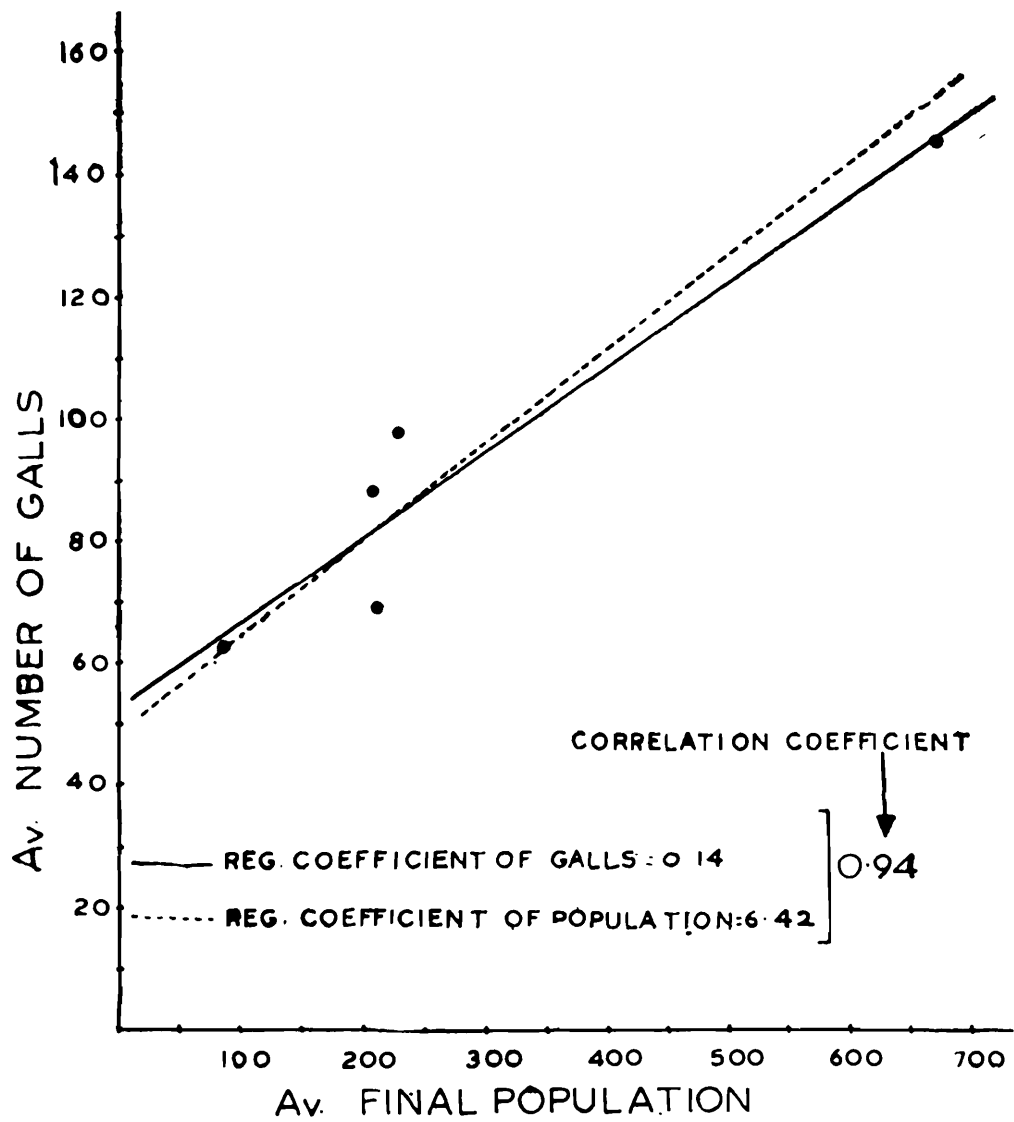


Fig.-1
(CORRELATION BETWEEN No. OF GALLS & FINAL POPULATION)

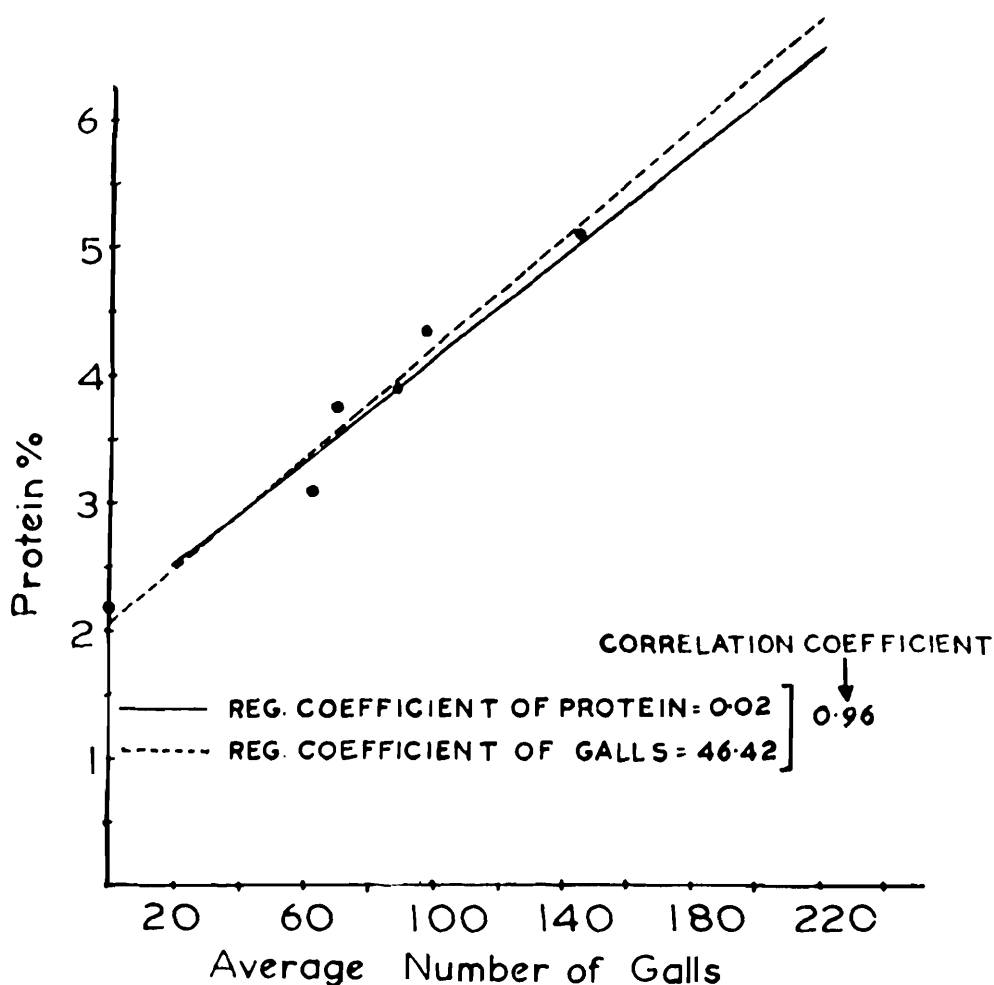


Fig.- 2

(CORRELATION BETWEEN NO OF GALLS & PROTEIN %)

DISCUSSION

The increases in shoot wt., shoot length, and root length in treated plants are significantly high, over the untreated ones and sometimes approached to the uninoculated control. The difference in galling incidences and final population is highly significant, between the treated groups and untreated inoculated control. The galling incidences and final population in the rhizosphere have definitely come down for the treatments. Maximum growth of the plants and maximum control of infestation are found among the *A. kadamba* treated plants and minimum control has been possible by the aldrin. Maximum galling and maximum growth of the parasitic population and highest ratio of protein are observed among the inoculated untreated plants and minimum galling, minimum growth of population and lowest ratio of

protein are found among the *A. kadamba* treated plants, almost nearer to that of uninoculated control.

This is clear from table 1 that whenever the population has been reduced and the galling incidences has been controlled this is also reflected in it's root protein ratio, which has been reduced proportionately. The coefficient of correlation between the final population and the galling incidence is 0.94 which indicates the correlation is positive and highly significant. Similarly the correlation between galling incidence and protein ratio is 0.96 which is also positive and highly significant. This may be concluded that the final population, the galling incidence, and the root protein ratio are correlated, and are directly proportional to each other.

ACKNOWLEDGEMENT

The author acknowledges the financial help of the University Grant Commission, which was available to run the project, where this work has been done, and express his sincere thanks to Dr. B. K. Tikader, Director, Z. S. I. for his permission and acceptance of the paper.

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EFFECT OF DIFFERENT TYPES OF CERCARIAL INFECTION
ON DIGESTIVE GLAND OF *LYMNAEA*
ACUMINATA (GASTROPODA).

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INTRODUCTION

Lymnaea acuminata f. *refescens* Gray is the common intermediate host of many types of Trematode larvae and the digestive glands are the primary site of infection. The majority of larval Digenetic trematodes causes many histopathological changes in Gastropod tissues and these are reported by Cheng and Snyder (1962); Wright (1966); Reader (1971) and Mohandas (1974a). A comparative studies have been made to observe the degree of pathological changes of the digestive gland due to infection of Xiphidiocercous; Furcocercous; Amphistome and Echinostome cercariae.

MATERIAL AND METHODS

The snails were collected from the ponds of different localities of West Bengal and only the adult (18-20 mm size) were brought to the laboratory for experiment. They were kept individually in separate specimen-tubes and maintained alive by changing water daily and fed with lettuce leaves. Infected snails were identified by liberation of cercariae and the moderately infected snails were taken for our observation. The different types of cercariae were identified. The part of the digestive glands were dissected out from both infected and non-infected snails. The tissues were quickly fixed in Zanker's solution and embedded in paraffin (60°C) and sectioned at 6 μ m. Tissues were stained in Haematoxylin-eosin.

OBSERVATION

(A) *Non-infected snails*—Histology of the normal digestive gland is lined up by thin connective tissue, known as Tunica propria. This

gland is made up of numerous lobes called Acinilobes (Fig. 1 and 2). Each lobe is made up of two types of cells—Acini cells and Calcic

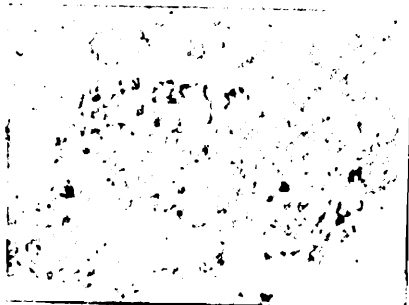


Fig. 1

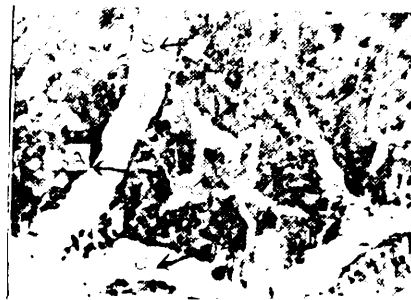


Fig. 2.

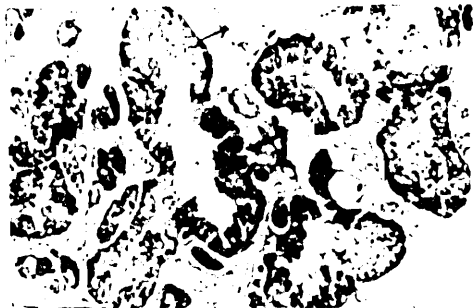


Fig. 3

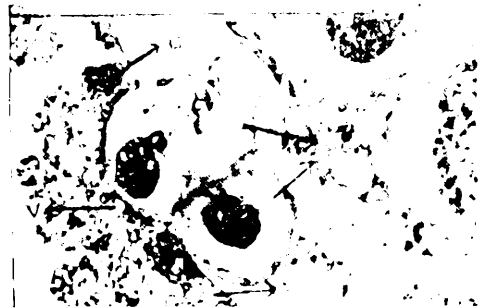


Fig-4

Figs. 1. Section of digestive gland of non-infected snails showing acinilobes (6x10x). 2. Section of enlarged view of acini lobe of non-infected snail (6x45x). 3. Section of digestive gland showing invasion of parasites (Furcocercal infection) (6x10x). 4. Section of enlarged view of Fig. 3—showing histopathological changes (6x45x).

A=Acinilobe,
C=Calcic cell,
P=Parasite

S=Excretory spherules,
V=Cytoplasmic Vacuole,

cells. Acini cells are columnar and nuclei are at the base. Cytoplasmic vacuoles are very frequent. Each lobe is provided with some brown coloured spherules, known as excretory spherules. Calcic cells are somewhat triangular deeply stained cells, which are present at the periphery of the lobes and their numbers are very few.

(B) *Infected Snails* (Table 1 and Fig. 3 and 4): The rupturing of tunica propria is a common phenomenon in all cases of infected snails. This is more prominent in case of *Xiphidiocercous* cercarial infection

than the Furcocercous and Amphistome cercarial infection. The Echinostome causes less damage in compare to others.

TABLE 1 : Showing effect of different cercariae on digestive gland of *L. acuminata* ('+' sign indicate the rate of change).

Types of cercariae	Rupturing of tunica propria	Disarrangement of acini lobules	Excretory spherules number	Calcic cells number	Cytoplasmic Vacuoles number
Furco-cercous	++	+++	+++	+++	++++
Xiphidio-cercous	+++	++++	++++	++	++++
Amphis-tome	++	++	++++	++	+++
Echinos-tome	+	++	+++	+	++++

The acini cells become more or less oval in shape and the nucleus becomes pyenotic. There is a lot of disarrangement of the acinal tubules. It has been observed that Xiphidiocercous cercarial caused maximum disarrangement of the lobules in comparable to Furcocercous, Amphistome and Echinostome cercariae respectively.

There is an increase in the number of calcic cells. The infection of Furcocercous cercariae caused innumerable increase of calcic cells than Xiphidiocercous and Amphistome. Whereas the number of calcic cells not increased significantly in case of Echinostome infection.

Cytoplasmic vacuoles increase in numbers in all cases except Amphistome, where it is very feebly increased.

The infection of Xiphidiocercous and Amphistome cercariae caused the increase in the number of excretory spherules than the Furcocercous and Echinostome type.

DISCUSSION

Cheng and James (1960), James (1965), Mohandas (1977) reported that the destruction of digestive gland acini in Mollusca by cercariae,

is due to mechanical destruction exerted by the parasites or lysis due to parasites excreta or autolysis due to starvation. Cheng and Snyder (1962) suggested that the increase in number of vacuoles by physiological degradation also. Mohandas (1974a), Reader (1971) and James (1965) reported that physiological starvation caused by occupying the space within the digestive gland by larval forms and result in the breakage of passage of nutrients and destruction of tissues are happened.

From the foregoing study, it has been observed that Xiphidiocercous and Furcocercous cercariae cause more damage on *L. acuminata* than Amphistome and Echinostome. It appears that damages are both mechanical and physiological. It has also been observed that the degree of damages are not related to the size of different cercariae.

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