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Seasonal prevalence and host visitation of *Mansonia* mosquitoes in Trivandrum city with a note on mite infestation

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Abstract. A study relating to seasonal prevalence and host visitation of *Mansonia* mosquitoes in Trivandrum city was carried out between August 1984 and July 1985. The area chosen was the one which is a perennial breeding source for *Mansonia* mosquitoes. Only *Mansonia uniformis* and *Mansonia annulifera* were prevalent in this area of which the former was found to be the predominant species. Decrease in the number of *Mansonia annulifera* from the survey conducted during the previous year may be due to the disappearance of *Pistia stratiotes* and its replacement by *Salvinia auriculata*. Rainfall and temperature are the two important environmental factors which influence the number of *Mansonia* mosquitoes visiting the host. The maximum number of adults of *Mansonia uniformis* was collected during February to June 1985. No swarm of *Mansonia uniformis* was encountered during the present study, however, males were found to wait and mate with the resting as well as blood fed females in the vicinity of the host. Both sexes of *Mansonia* mosquitoes were parasitized by *Arrenurus* and limnesiid species of water mites. Maximum parasitization was seen during July 1985.

Keywords. *Mansonia*: seasonal prevalence; host visitation; parasitization.

1. Introduction

Much emphasis has been laid on the problem of filariasis (both wuchererian and brugian) in India during the past few decades (Buck 1976; Sharma 1976; Das 1976). *Brugia malayi* filariasis is limited to small pockets in peninsular India and less common in North West (Chandrasekharan *et al* 1976). Three species of *Mansonia* mosquitoes viz *Mansonia annulifera*, *Ma. uniformis* and *Ma. indiana*, play an important role in the transmission of this disease, of which *Ma. annulifera* is the most important vector in Kerala state (Nair 1962; Nair and Roy 1958; Jaswant Singh *et al* 1956; Chandrasekharan *et al* 1976).

Taking into consideration the vectorial status of mosquitoes and in the absence of any previous entomological survey after 1938 relating to prevalence, seasonal fluctuations and host visitation, a study was undertaken in Trivandrum city. Trivandrum is a fast developing city and several marshy, water-logged areas suitable for the growth of *Pistia stratiotes*, *Salvinia auriculata*, *Eichhornia speciosa* etc., are being cleared off and filled up for building constructions. Ecologically the most fascinating aspect of Trivandrum is that though the city is being converted into a 'concrete jungle' with massive building construction, yet it is possible to see open drainage canals and paddy fields stocked with water plants.

2. Materials and methods

2.1 *The survey area*

An extensive survey of the breeding areas of *Mansonia* mosquitoes in Trivandrum district (total population 2,591,057 and population density 1,182/sq km) with special reference to areas in and around Trivandrum city (total population 4,82,722 and population density 6,442/sq km) was carried out. Though *Mansonia* mosquitoes were found breeding in 5 areas within the city limit (figure 1), the present study was concentrated on one of these areas called Kannanmoola. The study area has a canal

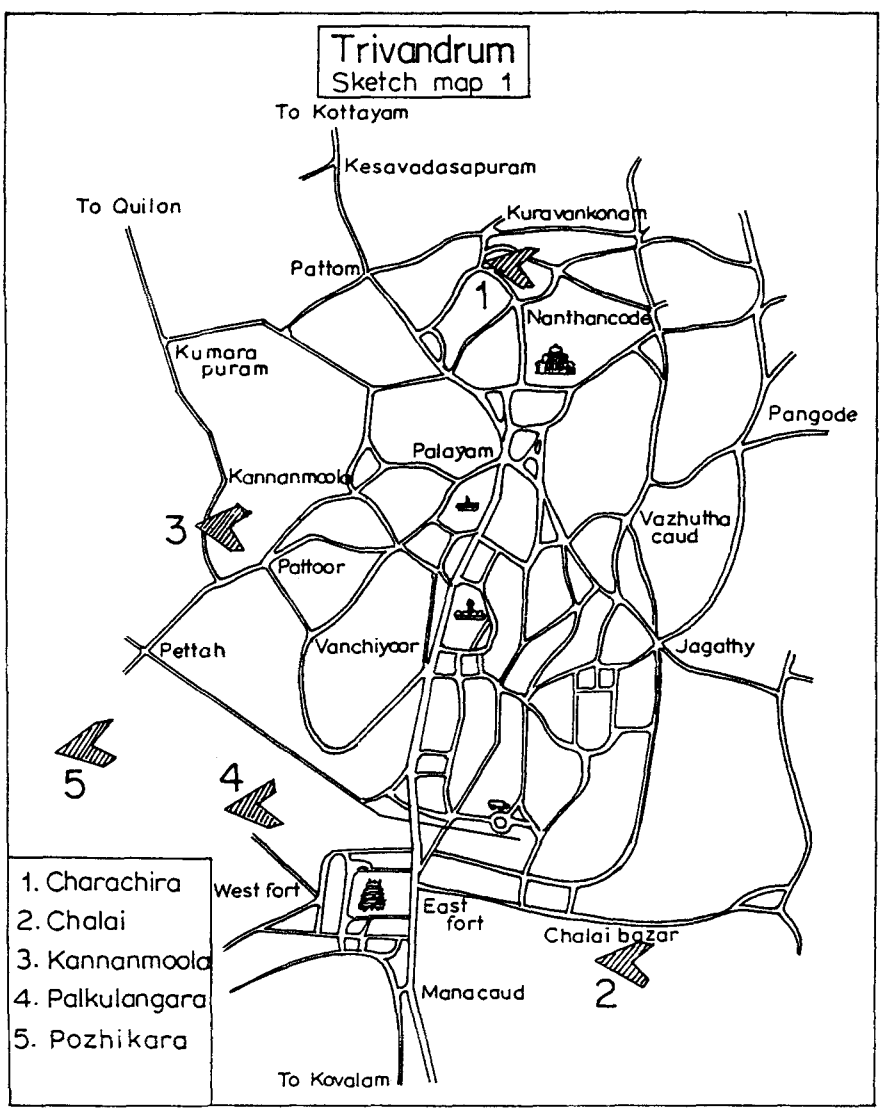

Figure 1. Map of Trivandrum city. Arrows show different collection spots of *Mansonia* mosquitoes.

Figure 2. Running water in the middle and intense growth of *Eichhornia speciosa* on either sides of the drainage canal in Kannanmoola in Trivandrum (× 750).

which runs through the city into which small canals from different parts of the city drain. The major canal empties into a lake about 3 km away from Kannanmoola. The canal is 3 m deep, characterised by running water in the middle and intensive growth of *E. speciosa* as the permanent aquatic plant on its either sides (figure 2). The study was started with areas where *Pistia* plants predominated, but are now being replaced by *S. auriculata.*

2.2 *Meteorological conditions*

Necessary data relating to temperature, rainfall, humidity and wind velocity were procured from the Central Meteorological Department, Trivandrum, which is located about 5 km away from the study area.

2.3 *Adult mosquito collection*

The adults of *Mansonia* mosquitoes were collected from a cattle shed located very near to the canal in Kannanmoola, twice a week between 18·45 and 19·30 hr. The cattle shed was illuminated with a 60 watt bulb and the mosquitoes were hand collected using test tubes (WHO 1975). A flash light was used during the collection. The number of mosquitoes per man hr for each collection was calculated. The field-collected mosquitoes were brought to the laboratory, identified, examined for mite infestation and the presence of fresh blood in the gut. The parasitic mites infested on the adult mosquitoes were sent to Dr G R Mullen, Auburn University, USA, for identification.

2.4 *Study on swarming mosquitoes*

In order to study the swarming behaviour of *Mansonia* mosquitoes in and around the survey area, swarming insects were collected by hand net as described by WHO (1975).

Collections were made during 18·30–19·00 hr. Insects thus collected were brought to the laboratory and identified.

2.5 *Statistical methods*

In order to bring out any possible correlation between physical factors like temperature, rainfall, wind velocity and the fluctuations in the host visiting populations of *Mansonia* mosquitoes, statistical methods like Partial correlation and Student's '*t*' test were used.

3. Results

3.1 *Adult mosquito collection*

Of the total of 8,113 mosquitoes collected during the period of the study, *Mansonia* species constituted 65·32% (5301). Of these, 97·66% were *Ma. uniformis* and only 2·34% were *Ma. annulifera*. Other mosquitoes species collected during the study are shown in table 1.

3.2 *Seasonal fluctuation of Ma. uniformis in the whole year*

Figure 3 depicts *Mansonia* mosquitoes collected, in relation to rainfall and temperature during the one year period of study. Though *Ma. uniformis* was represented in the year-round collection, the number of mosquitoes visiting the host during the study period varied from 1–194 mosquitoes/man hr. The maximum number of *Ma. uniformis* was collected in February 1985 (118 mosquitoes/man hr) and minimum in October 1984, (35 mosquitoes/man hr). One of the characteristic features of the collection was the presence of males of *Ma. uniformis* in fairly large numbers in the cattle shed whereas males of no other mosquitoes were found in the shed.

Table 1. Other mosquito species collected during August 1984 and July 1985.

Name of species	Frequency	Peak period
Culex gelidus	Very common	Nov.–March
Cx. sitiens	Very common	Nov.–March
Anopheles hyrcanus	Common	June–August
Aedes vexens	Less common	—
Ae. vittatus	Less common	—
Armigeres subalbatus	Less common	—
Ficalbia chamberlaini	Less common	—
An. jamesi	Rare	—
An. vagus	Rare	—
An. barbirostris	Rare	—

Note: Very common—>60% of mosquitoes other than *Mansonia*. Common—>15%. Less common—<7%. Rare—one or two during the whole year.

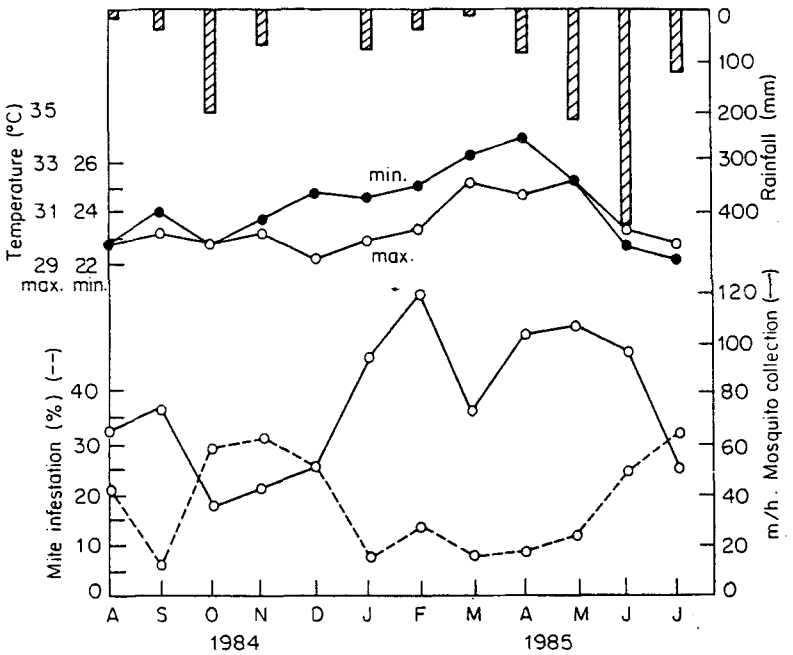

Figure 3. Seasonal prevalence and host visitation of *Mansonia* mosquitoes in Kannanmoola, Trivandrum city, in relation to rainfall, temperature (minimum and maximum) and percentage of mite infestation.

3.3 *Influence of climatic factors on the prevalence of Mansonia mosquitoes*

The rainy season was between April–July and October–November, during the period of study. The monthly mean maximum temperature during the hottest month (April) went up to 33·9°C and the monthly mean temperature in the coldest month (December) went down to 22·1°C. Wind velocity was maximum during June and minimum in December. As it is evident from figure 3, there was a steep rise in the number of mosquitoes visiting the host from October–February. This obviously was a peak period of collection of mosquitoes (35–118 mosquitoes/man hr). In the subsequent months though there was a slight fall in the number of mosquitoes it never reached as low as that of October. But during April–May the number remained high. There is a sudden fall during June–July month. Statistical analysis has shown that minimum temperature and rainfall are the two environmental factors which show correlation with the flight activity of the mosquitoes. As it is evident from table 2, minimum temperature and rainfall have correlation coefficient of 0·34 and 0·76, respectively with the number of adult mosquitoes. Both are significant at 5% level with a t-value of 3·27 and 2·44, respectively. It can be surmised from figure 3 as well as the statistical calculations that the highest activity of mosquitoes appears to fall during the period when the minimum temperature falls within the range of 23–25°C.

The influence of the minimum temperature is something which can easily be understood as the collections were made at dusk. However high the day time temperature may be, it could not affect the mosquitoes because this constitutes the resting phase in their daily activity rhythm.

Table 2. Showing correlation matrix between total adults collected, temperature, rainfall and wind velocity.

	A	T_{max}	T_{min}	R_f	W_v
A	1	0·026	0·34[a]	0·26[a]	−0·11
T_{max}		1	0·48	0·38	−0·37
T_{min}			1	0·76	−0·64
R_f				1	−0·47
W_v					1

[a]Significant at 5% level.
A, Adult mosquitoes; T_{max}, temperature maximum; T_{min}, temperature minimum; R_f, rainfall; W_v, wind velocity.

A sudden decrease in the number of adults visiting the host during June–July appear to have some correlation with the onset of rain. There appears to be a decline in the number of mosquitoes visiting the host during onset of the monsoon months. Kerala gets two monsoon periods, the North–East in October and November and South–West in July and August. These are the two periods when a sharp decline in the number of mosquitoes visiting the host is observed.

3.4 *Swarming and mating*

The swarm encountered in the study area consisted almost entirely of *Culex gelidus*. It is of great importance to notice that no *Mansonia* mosquito was collected during any time of the year from the mosquito swarm examined. It should also be noted that only males of *Ma. uniformis* were collected from the cattle shed from where the routine collection was made. It was also observed from the hand net collection that it was the male *Ma. uniformis* which arrived first to the cattle shed followed by the females.

3.5 *Mite infestation*

Of the 5,182 *Ma. uniformis* collected 20·78% were found to be parasitized by water mites. The incidence of parasitization of *Ma. uniformis* male mosquito was 24·52% whereas that of female was found to be only 14·37%. Of the 121 female *Ma. annulifera* collected only 18 (14·88%) were infested by water mites. Since, only the larval stages of mites associated with the adult mosquitoes were encountered during the present study, their determination at species level was found to be difficult. However, based on larval features alone, they were determined to be two species of *Arrenurus* (family—Arrenuridae) which were tentatively designated *Arrenurus* species A-B, and a limnesiid (family—Limnesiidae) by Mullen G R (unpublished results). Of the total *Arrenurus* infested mosquitoes, collected from the study area, 51% were found to be attached to the cervical region, 48% to the abdominal region and 1% to the other regions like head, proboscis, leg and wing. With regard to limnesiids, they were primarily attached to the cervical region, accounting for 96·6% of the attachments. Only a few were attached to the abdominal venter and wing. Simultaneous infestation by both species of *Arrenurus*

and limnesiids on the adult *Mansonia* mosquitoes is a common feature observed in the present study. *Arrenurus* species preferred to be attached on the abdominal venter and that of limnesiids on the cervical region.

The graph relating to abundance of infestation shows a typical bimodal one, but in the reverse pattern. There appears to be a reverse relation between the rate of mite infestation and the total number of mosquitoes caught. Maximum infestation of mite on the adult mosquitoes appear to be from October–December 1984, and June–August 1985, the periods when the number of *Mansonia* mosquitoes collected was minimum.

4. Discussion

It appears that the entomological survey of *Mansonia* mosquitoes carried out in Trivandrum city during the course of the study is the first of its kind after Iyengar (1938). It is a well known fact that *Ma. uniformis* is the principal potential vector of *B. malayi* infection. Nevertheless, the existing records show that at present Trivandrum is free from *B. malayi* infection. However, *B. malayi* infection is still present in small pockets of Alleppey district in Kerala. As there is constant movement of people between these two places, the possibility of introduction of *B. malayi* infection into Trivandrum city cannot be ruled out.

Earlier work carried out so far, in Kerala has shown that the peak season for *Ma. annulifera* was from January–June (pre-monsoon species) and that for *Ma. uniformis* was from July–November (post-monsoon species). The most favourable period for *Ma. annulifera* appears to be the most unfavourable period for *Ma. uniformis* and *vice versa* (Chandrasekharan *et al* 1976). The factors which regulate 'favourableness' and 'unfavourableness' are not known. However, in the present study, the 'favourable' or 'unfavourable' phenomena exhibited by these two species of *Mansonia* mosquitoes have not yet been encountered during the one year period of study. Moreover, a perusal of the annual trend of density of these *Mansonia* mosquitoes during host visitation, in 1984–85, showed a declining trend for *Ma. annulifera* and highly fluctuating trend for *Ma. uniformis*. Earlier studies carried out during 1931–34 by Iyengar (1938) and in 1956 by Jaswant Singh *et al* (1956) showed that in Trivandrum, *Ma. annulifera* was the most predominant species among *Mansonia* mosquitoes. During those periods *Ma. annulifera* bred in abundance on roots of *P. stratiotes*, commonly observed in tanks, canals and rivers of Kerala State (Burton 1959). Subsequently, an introduced water fern, *S. auriculata*, during 1960, crowded out *Pistia* and formed an impervious growth that increased larval mortality (Joseph *et al* 1963), which in turn, will naturally reflect upon the declining trend of *Ma. annulifera* population.

Major ecological change noticed in *Mansonia* breeding areas in Trivandrum city, during the present study is the disappearance of *P. stratiotes* which is now replaced by *S. auriculata*. Another noteworthy feature which need mention here is that, during 1983, of the total adult *Mansonia* mosquitoes emerged in the laboratory, *Ma. annulifera* constituted 55·3% from the field collected larvae, whereas, it was only 9·88% in 1984. Moreover, in 1983, when the survey of *Mansonia* larvae were conducted in Kannanmoola area, the *Pistia* plants were present as thick beds which gave harbourage for the imaginal stages of *Mansonia* mosquitoes. Unfortunately,

during the survey in 1984, the *Pistia* plants had almost disappeared from the canals, leaving only small patches of *Pistia* in between the *S. auriculata* or *E. speciosa*. Any possible correlation between the decline in the population of *Ma. annulifera* and the disappearance of *Pistia* plants needs further study. However, it may be noticed that *Ma. uniformis* was unaffected by these changes. They appear to have adapted themselves to other aquatic plants especially *Eichhornia*. The laboratory studies have also shown that *Ma. uniformis* can well thrive on other aquatic plants like *S. auriculata*, *E. speciosa*, *Ipomoea aquatica*, *Commelina nudiflora* etc.

Very little information is available on mites parasitizing mosquitoes in India. Of the known 11 acarine families containing species known to parasitize or prey on mosquitoes (Mullen 1975a; Smith 1983), only two representatives from the families of prostigmatid water mites (family Arrenuridae and Limnesiidae) were reported in the present study.

The infestation of *Arrenurus* mite was reported on various species of mosquitoes like *Aedes*, *Anopheles*, *Culex*, *Culiseta*, *Ficalbia*, *Hodgesia*, *Mansonia* and *Uranotaenia* (Smith 1983). In Asia *Arrenurus* species have been known to parasitize a total of 12 species of *Anopheles*, *Culex* and *Mansonia* (Reisen and Mullen 1978). Of the various species of mosquitoes collected during the present study only *An. hyrcanus*, *Ma. annulifera* and *Ma. uniformis* have been found to be parasitized by *Arrenurus* species A and B. However, no other mosquito collected during the present investigation were found to be parasitized by these water mites.

Limnesiid mite larvae parasitizing *Mansonia* mosquitoes reported in the present study is the first of its kind in India as the earlier workers have observed only *Arrenurus* species parasitizing mosquitoes (Saxena and Sharma 1981; Rahman *et al* 1979; Malhotra *et al* 1983). Insofar as is known, limnesiid larvae have been reported from a number of *Mansonia* species in Uganda and Indonesia (Mullen 1975a; Smith 1983). During the present investigation, limnesiid larvae were found to have a clear host preference for *Ma. uniformis* readily parasitizing both sexes. Moreover, most of these water mites were preferred attached to the cervical region of these mosquitoes, although occasionally specimens were found on the abdominal venter and wing.

Since Gillett (1957) first proposed that the presence of parasitic water mites on female mosquitoes can serve as an indicator of host's nulliparity, considerable work has appeared in the literature regarding the topic. More recently, Service (1973) and Mullen (1975b) supported Gillett's view. The present study is also in conformity with the findings of Gillett (1957) i.e., 80% of the total mite infested mosquitoes examined so far, for physiological age determination, were found to be nulliparous.

When the abundance of parasitic mites collected during the study period was compared, the mean parasitic load was higher for *Ma. uniformis* females than for the males. One should remember that with regard to *An. hyrcanus*, no male was collected from the cattle shed (some of the females of *An. hyrcanus* were infested with water mites). A bias for female hosts would be advantageous because male mosquitoes are much less likely to return to water after emergence (Stechman 1980; Smith and McIver 1984). The apparent sex bias is due to male abundance (male emergence precedes female emergence) correspondingly closer to female emergence rather than the mites discriminating between sexes (Smith and McIver 1984).

In the present study, mite infestation on adult *Mansonia* mosquitoes was maximum from October–December 1984 and June–August 1985, during which the number of mosquitoes collected was minimum. In spite of the fact that some of the

mosquitoes are heavily parasitized by these water mites, the mosquitoes fly from their breeding source to the host for their blood meal. However, the heavy infestation of these water mites influencing longevity, flight activity and reproduction are yet to be studied in detail.

Two important physical factors which appear to influence the number of mosquitoes visiting the host during the one year study were temperature and rainfall. The minimum temperature has the best correlation with the host visiting abundance of *Mansonia* mosquitoes, whereas the maximum did not show statistical significance. Earlier workers like Hayes and Hsi (1975) and Hayes and Downes (1980) reported a correlation with the temperature and population abundance with *Culex pipiens quinquefasciatus* and indicated that temperature dependence is interwoven throughout all stages of the mosquitoes' life cycle. In the present study, when the temperature is high the *Mansonia* mosquitoes visiting the host were found to be high.

It is possible that rainfall also has some indirect influence on the number of mosquitoes visiting the host. The finding reported here clearly documents the correlation of host visitation abundance of *Mansonia* mosquitoes with rainfall in Kannanmoola. There appears to be a sharp decline in the number of mosquitoes visiting the host during the onset of monsoon periods. The correlation for *Mansonia* mosquitoes using partial correlation and Student's '*t*' test suggest that very large increase in the rainfall may not be accompanied by proportionately large increase in the number of the mosquitoes visiting the host. These findings are consistent with those of Reisen *et al* (1977) and Olson *et al* (1983) reported for *Culex* mosquitoes. The close correlation and relative abundance of *Mansonia* mosquitoes visiting the host with rainfall provides an extremely useful index for prediction of success of hand collection of these mosquitoes based on data readily available from almost any *Mansonia* breeding area.

The total rainfall was high during April–July 1985. Correspondingly an increased number of *Ma. uniformis* was observed during the same period. In contrast, during October 1984, though the rainfall was 215·1 mm the number of host visiting mosquitoes was less. It is possible that due to sudden flooding in October (North East monsoon period) the canals were flooded with water and thus the velocity of the running water was increased. Owing to the flooding and strong water currents in the canals, aquatic plants like *Eichhornia*, *Salvinia*, *Pistia* etc., were carried from their original place to a distant area. Usually, these aquatic plants, especially *E. speciosa*, will have their roots buried in the top layer of the loose silt in water. One should bear in mind that, the imaginal stages of *Mansonia* mosquitoes are attached to the roots of these aquatic plants for their various physiological processes in their breeding grounds. Thus due to flooding and strong water currents, the aquatic plants along with the imaginal stages of the mosquitoes were uprooted and carried to a far off place from the original breeding site. Moreover, after emergence the mosquitoes from these areas may find it difficult to reach the original breeding grounds and visit the host for their blood meal. Thus, obviously, there was a decrease in the number of mosquitoes visiting the host in the study area. This holds true in the present study, during October and November 1984.

The present study clearly brings out the fact that there was no swarm of *Ma. uniformis* as observed in other species of *Mansonia* (Jayawickreme 1953—cited by Mattingly 1957; Neilson 1964). Swarming and mating behaviour of *Mansonia* mosquitoes were

studied earlier by Shute (1930), Jayawickreme (1953—cited by Mattingly 1957) and Neilson (1964). During swarming, the males of *Ma. uniformis* wait in a zone which is likely to be traversed by females as in the case of some Simuliids where the males swarm over cattle and catch the female as they come to feed (Wenk 1965).

It appears that males locate the host and arrive at the site early and wait for the females to come. Males were found to mate with resting as well as blood fed females in the vicinity of the cattle. Field experiments conducted by McIver (1980) and McIver *et al* (1980) demonstrated that male *Mansonia* mosquitoes were attracted to hosts from at least 3 m and their density was found to be significantly greater than at a distance of 7 m from the bait for the females. The sensory stimulus used by *Mansonia* males in orientation are in all probability, olfactory cues contained in the odour plume emanating from the host (McIver 1980). The use of olfactory cues for long range orientation as reported by McIver (1980) is probably the most important mechanism operative in *Ma. uniformis*. This kind of behaviour might have facilitated in the present investigation for the mate-finding phenomenon, to bring the sexes together in the vicinity of the host.

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