2. Review of literature

Of all the medically important insects Phlebotomid sandflies are the most difficult vectors to study, due to their tiny size with nocturnal activity (Killick-Kendrick, 1978). In India this species is being given much attention in recent years because of resurgence of sandfly borne diseases in many parts of the country.

The genus Phlebotomus was first described by Rondani in 1843 (Peters & Killick-Kendrick, 1987) and the species papatasii was described and nomenclatured by Scopoli as Bibio papatasii in 1786. Later this species was redescribed as Phlebotomus (Phlebotomus) papatasii (Scopoli) by Sacca in 1950 (Lewis, 1967). The Phlebotomus papatasii (Scopoli) is being used at present for the specimen seen in Oriental region. A specimen of this species described by Gmelin was also redescribed as Phlebotomus papatasii by Grassi in 1907 (Lewis, 1967). The Phlebotomid sandflies which were kept under the family Psychodidae were given a family status as Phlebotomidae, using characters that are fundamental and peculiar to them (Abonnenc and Leger, 1976).

P. papatasii has a wide distribution, mainly in tropics and sub-tropics. The northern limit in Europe is Paris and in eastern Asia, they cover as far north as Manchuria. They are prevalent over
the whole continent of Africa, south and central Asia and also occur in the northern part of Australia and New Guinea (Adler and Theodor, 1957). Smith in 1959 stated that sandflies were in variable densities in every state in India. In the oriental region, Lewis (1978) recorded a total of 124 taxa, represented by two genera viz., Sergentomyia and Phlebotomus.

Although sandflies were supposed to be confined up to an altitude of 600 mts. sandfly population was recorded in Mettupalayam at an altitude of 800 mts. and later even at an altitude of 1200 mts. (NICD, Annual Report, 1980). P. papatasi was recorded in Jammu and Kashmir also at an altitude varying from 670 to 1,640 mt. (Zahar, 1979).

Bhat and Modi (1976) examined the mitotic karyotype of the brain cells of fully grown larva of P. papatasi and found 4 pairs of chromosomes (2n = 8). Abnormalities in the male genitalia particularly in the surstyle and dististyle were reported by Kaul and Wattal (1979) during an entomological survey in Bihar. Similar observations were found in the genitalia of a male P. papatasi in Tunisia also (Dancesco and Chadli, 1979). Abnormality in the male genitalia of P. papatasi was also reported by Kaushal Kumar and Raiamonnal (1988) from Gujarat recently.

There are extensive reports on the distribution and abundance of
sandflies throughout the world. In the west coast of India, McCombie Young in 1927 studied the Phlebotomines of Bombay state in detail and obtained \( P. \) \textit{argentipes} and \( P. \) \textit{papatasi} in large numbers with one specimen each of \( P. \) \textit{thapari} and \( P. \) \textit{chakravarthy}. In Hyderabad city (Andra Pradesh) \( P. \) \textit{papatasi}, \( P. \) \textit{argentipes}, \( P. \) \textit{colabaensis}, \( S. \) \textit{shortti}, \( S. \) \textit{bailyi}, \( P. \) \textit{antennatus}, \( S. \) \textit{dentatus} and \( S. \) \textit{endithae} were recorded, where both \( P. \) \textit{papatasi} and \( P. \) \textit{argentipes} were found to be more common than other species (Outubuddin, 1944). Jacob and Kalra (1951) conducted a survey during 1949-50 in Jammu and Kashmir and recorded \( P. \) \textit{papatasi} at an altitude of varying from 2,000 to 5,400 feet. Mitra in 1956 reported the presence of \( P. \) \textit{argentipes}, \( P. \) \textit{papatasi}, \( P. \) \textit{argentipes} var. \textit{glaucus}, \( P. \) \textit{squamipleuris} var, \textit{poonaensis}, \( P. \) \textit{smithi}, and \( P. \) \textit{thapari} in Poona and he also observed that \( P. \) \textit{argentipes} was common in cattle sheds and \( P. \) \textit{papatasi} in houses. \( P. \) \textit{papatasi} was encountered in all localities in the south and eastern part of Kashmir by Mitra in 1959. Sandfly fauna of Indian sub-zone was represented by 46 species which include important vector of leishmaniasis (Lewis, 1967). The occurrence of sandflies in Rajasthan was reported by Kaul et al. during 1973.

In the southern tip of the peninsular India, Barraud studied the sandfly fauna in 1926. In 1956 a survey in the same city yielded \( P. \) \textit{papatasi} and \( P. \) \textit{argentipes} showing local uneven distribution of sandflies (Rathnasamy and Ramakrishnan, 1954). Shanmugam et al. (1977) summed up the results of sandfly surveys carried out in Tamil
Nadu, since 1953 with an exception for a period from 1955 - 1968 when no collections were organized. In this survey 4 species of sandflies were obtained of which *P. papatasi* was found to be more abundant. Sivaprakasam *et al.* (1988) when studied the bionomics of sandflies, they reported that *P. papatasi* was the commonest species in Madras.

Dhanda and Modi (1971) studied the species composition of sandflies in some area of Maharashtra. Out of 5,727 sandflies obtained, 93.7% were *P. papatasi*. When a survey was made by Modi *et al.* (1978) in all 26 districts of Maharashtra State, a total of 38,113 sandflies were collected from different habitats such as tree holes, termite mounds, rodent burrows, rocks and cracks and crevices, where *P. papatasi* was most common in human dwellings followed by mixed dwellings and cattle sheds. In Orissa *P. papatasi*, *P. salehi* and *S. clydei* were reported to occur in areas known for transmission of cutaneous leishmaniasis among rodents (Kaul *et al.*, 1976).

In 1977 Modi *et al.* reported from Bankura Dt. in West Bengal 9 species of sandflies viz., *P. argentipes*, *P. papatasi*, *P. colabaensis*, *S. bailyi*, *S. babu*, *S. eadithae*, *S. punjabensis*, *S. shortti* and *S. squamipleuris*. Another investigation in Poona in 1978 by Modi *et al.* revealed that apart from the two vectors i.e., *P. papatasi* and *P. argentipes*, the other species present were *S. babu*, *S. bailyi*, *S. clydei*, *S. punjabensis*, *S. indica*, *P. colabaensis* and *S. iyengari*. All but the last two were from indoors and the remaining
species were from outdoors and they occurred throughout the season with a maximum during monsoon and post monsoon months and minimum in winter and summer.

In Surat (Gujarat) sandfly fauna was studied by Pandya et al. (1977) in the late 1970s. They found that P. papatasi was most common and was followed by P. argentipes, S. montana, S. punjabensis, S. minuta and S. theodori. Among the species recorded only P. papatasi was found to occur throughout the year. Kaul et al. in 1979 collected P. argentipes, P. papatasi, P. stantoni, P. colabaensis, S. babu, S. kauli, S. indica and S. christophersi in Bihar, where P. papatasi occurred nearly in all the houses. Kulkarni et al. (1978) also reported the abundance and distribution of sandflies in Bihar. Seven species of sandflies including P. papatasi were reported from indoor and outdoor habitats from Pondicherry by Shetty and Rajagopal in 1979.

The species composition of sandfly in Bihar was studied by Dhanda et al. in 1982. They collected 13,510 sandflies representing 10 species viz, P. argentipes, P. papatasi, P. colabaensis, S. babu, S. indica, S. punjabensis, S. shortti, S. bailyi, S. iyengari and S. clydei. Among them P. papatasi was the most abundant species.

In an endemic area of Bastar (Madhya Pradesh) the presence of sandflies was reported for the first time in 1983. The most abundant
species were S. bailyi, P. argentipes, P. papatasi and S. punjabensis (Shetty and Kulkarni, 1983).

Recently the prevalence of P. papatasi in Sabarkantha dt., Gujarat was reported by Kaushal Kumar and Rajagopal in 1988. The occurrence of sandflies such as P. papatasi, P. argentipes, P. colabaensis, S. babu, S. punjabensis, S. indica and S. clydei was also revealed by Kaushal Kumar et al. in 1988 from indoor and outdoor situations from Delhi and its environs.

The medical importance of sand flies has been worked out by many people. As early as in 1913, Loughman reported that P. papatasi was responsible for the papatasi fever in Aden. Bellile (1913) confirmed the correlation between sandfly population and papatasi fever in Suda Bay during 1910-1912, particularly in hot and dry summer. Smith and Loughman (1914) investigated and proved that the papatasi fever was transmitted by P. papatasi. Graham (1915) reported the occurrence of sandfly fever in foot hills of Himalayas and he named it as Peshawar fever. In the Eastern Mediterranean, Higgins (1916) had reported that sandfly fever was due to P. papatasi. When the people were asked to sleep outside, the disease had disappeared. Phlebotomus fever virus was isolated from both sandflies as well as from human beings (Goverdhan et al., 1976) from Maharashtra, India. Goverdhan et al. in 1982 demonstrated the vector potential of P. papatasi to Sicilian virus.
It was Battistini (1931) who confirmed that Verruqu caused by Bartonella bacilliformis was transmitted by P. papatasi in Peru. Apart from their importance as disease vector, P. papatasi may constitute a serious but localized biting nuisance. In previously sensitized people their bite may result in severe and almost intolerable irritation, a condition known as in the Palestine as "Harara" (Theodor, 1935).

Mackie pronounced the association between leishmania flagellates and sandflies during 1914. Later Sergent et al. (1915) reported the occurrence of flagellates in biskara sore among infected human population. He observed that 'biskra sore' was common among people who were residing in houses infested with sandflies. When he examined the Geckos found in those houses, he obtained leptomonads resembling those found in wound of persons having biskra sore.

P. papatasi had been considered as the inoculator of oriental sore by Chatton & Blanc in 1918. It was Patton (1919) who explored the role of P. papatasi as a transmitter of both sandfly fever and oriental sore. He suspected further that Herpetomonas phlebotomini was the agent causing kala-azar, which reaches adults through the larvae from the soil while feeding, when the adults feed on a human host, they deposit the parasites on to his skin. In India, Sinton (1925) worked out on the role of insects of the genus Phlebotomus in the transmission of disease and he found out that P. papatasi was
responsible for oriental sore.

The history of experiments leading to the incrimination of the vector of kala-azar dates way back into the latter part of the 19th century and the first half of the 20th century. In an experiment Patton (1913) demonstrated the development of Herpetomonos in Cimex rotundatus and C. lectularius but he reported that the parasites in the bug died instead of multiplying. Wenyon in 1913 believed that the fleas such as Ctenocephalides canis and Pulex irritans play a role in the transmission. The transmission problem was pondered by Knowles et al. in 1923. They hypothesized that the flagellate were neither transmitted from man to man by contact nor by contamination since the parasites were found to occur in the peripheral blood and they suspected that insects as the transmitters, but they did not prove the transmission with any of the insects.

Adler and Theodor (1926) carried out an experimental transmission of cutaneous leishmaniasis to man from P. papatasi successfully, which was fed on a case of oriental sore. The relationship between P. papatasi and oriental sore was established by Sergent and Parrot during 1926. Napier and Smith (1927) carried out a study on the distribution of P. papatasi in India and observed that the prevalence of P. papatasi did not coincide with that of kala-azar. They also observed that when P. papatasi was fed on a kala-azar patient, 2 out of 101 picked up infection. Wenyon (1932) declared that Leishmania
was the obligatory parasite of sandflies. Alder and Theodor (1932) in Malta during 1931 examined 100 dogs and they found out only 11 were naturally infected with the canine kala-azar. When P. papatasi was fed on these dogs none of the sandflies developed infection. However Cachia and French in 1964 declared that P. papatasi also play a role in the transmission of kala-azar in this country.

Shortt et al. in 1935 after reviewing the literature on the incrimination of vectors of cutaneous leishmaniasis, concluded that P. papatasi and P. sergenti were the vectors of cutaneous leishmaniasis in the Old World. The same authors at Kasauli reported that wild caught females of P. sergenti harbour L. tropica. Latnishev and Kryukova (1941) carried out an investigation on animal reservoirs of cutaneous leishmaniasis in southern Turkmanistan in 1937 – 38 and found that gerbills, Rhombomys opimus and Mariones erythrosus were found to harbour the Leptomonads.

Adler and Ber in 1941 demonstrated the experimental transmission of L. tropica using laboratory bred P. papatasi. Out of 9 human volunteers exposed to infected sandflies, only 5 developed infection. Natural infection of P. papatasi in Andhra Pradesh, India was reported by Farooq & Qudubuddin in 1945. Of the 200 females of P. papatasi dissected 2 were found with flagellates in the midgut. Neronov & Gunin (1971) reported the natural foci of zoonotic cutaneous leishmaniasis and its relation to climatological
conditions. Sharma et al. (1973) updated the knowledge of the
distribution and prevalence of cutaneous leishmaniasis in India by
screening the records of cases reported from endemic areas. At the
same time the authors examined the history of anti malaria house
spraying in endemic belt extending from Amristar to Bhuj (Gujarat)
through Haryana and Rajasthan. They observed that the DDT spraying of
National Malaria Eradication Programme (NMEP) greatly reduced the
incidence of cutaneous leishmaniasis in the whole endemic belt,
however, there was an outbreak of cutaneous leishmaniasis during 1971
in Bikaner town, Rajasthan. Lodha et al. (1971) when examined 20 dogs
around the boys hostel at Bikaner by blood smears from ear tips,
impression smears from the congested nasal mucosa and thick smears
from the edges of cutaneous lesions, all blood smears were found to
be negative but the impression smears from 8 dogs were found to be
positive for *L. tropica*. In addition to dogs, *Tatera indica indica*,
a rodent was the most predominantly affected animal in this area.
Selim and Kandil (1972) stated that cutaneous leishmaniasis has been
frequently encountered in Kuwait, particularly in winter month at a
rate of 0.2 - 0.34%.

When the Rajasthan Canal Zone was surveyed by Sharma et al. in
1973 an undetermined *Phlebotomus* species and *S. clydei* were caught
from burrows of the Indian gerbil, *Meriones hurrianae*. The presence of
these sandflies in the animal burrows suggests the role of animal
reservoir in the transmission of cutaneous leishmaniasis. Later Kalra
and Lewis (1976) identified those *Phelebotomus* species as *P. salehi*. When *P. papatasi* obtained in rodent burrows, situated near human dwelling were examined for the *Leptomonads*, they were found to be negative.

In India the involvement of *P. papatasi* in the transmission of visceral leishmaniasis was suspected by Modi *et al.* in 1979. When a survey was carried out in a kala-azar endemic area of Bihar, they obtained 680 sandflies of which 27 were found to be infected with *Leptomonads* and the percentage of natural infection observed was 88.89 in *P. papatasi*, 7.41 in *S. balyi* and only 3.70 in *P. argentipes*. Sukkar *et al.* (1985) reported that *P. papatasi* is the possible vector of infantile kala-azar in Iraq. The relationship between sandfly bite and lesion was also worked out by Strelkova *et al.* (1980). They proved that not more than 2 leishmania lesions on an average develop after single sand fly attack, since *P. papatasi* may take several exploratory punctures when choosing a feeding site.

The ultrastructure of *L. tropica* was described on the basis of scanning electron microscopy in USSR by Shatova *et al.* in 1984. *Invitro* culture of *Leishmania* parasite has been attempted by Tesh and Modi in 1984.

When *P. papatasi* was experimentally infected with microfilariae of *Thomogadia ivaschkini* in USSR, it migrated into the haemocoel and
underwent further development in the flight muscles (Reznik, 1982).

Though sandflies had received much attention, information on their breeding sites are scanty. Having originated from aquatic ancestor the larvae have become adapted to live in moist soil. The larvae were reported to need water which may be bound by capillarity (Kalra et al., 1986). The larvae absorb water with their food and also through the skin. Sandflies were reported to breed in places where humidity level approaches 100%. (Kalra et al., 1986). The natural breeding of P. papatasi was found in half dried algae just above the water level on the sides of open cistern (Brunetti, 1913). Howlet (1914) also reported breeding of P. papatasi in nature during 1912 - 1913 in Calcutta, India. King (1914) unearthed a single larvae of P. papatasi from soil in a cotton field at Tokar in the Anglo Egyptian Sudan. Marett in 1915 had reported that P. papatasi selects dark and damp places for breeding. He also investigated that this insect breeds in caves and embankment. In Lahore when Mitter (1919) examined materials from drains, dried up cesspits, damp bricks, manure heaps, disused poultry houses made of bricks and clay, cow shed and latrines he obtained larvae and pupae of P. papatasi. In Old World, investigators have seldom found more than a few larvae. McCombie Young et al. in 1926 obtained larvae of P. papatasi in Peshawar district. In urban areas larvae were obtained from rooms and cattle sheds, floor cracks, crevices between loose bricks and rat burrows (Napier & Smith, 1926). McCombie Young et al. in 1926 made a
comprehensive work on the bionomics of *P. papatasi* particularly regarding its breeding habitats in Peshawar, India. Short *et al.* (1930) noticed that damp soils in human dwellings are the natural breeding site of *P. papatasi* in India. In rural areas breeding sites were debris in corners of soil floors of rooms and cattle sheds as well as plinth shaded site of huts, under feeding trough etc. Other outdoor breeding places were under thick vegetations, around roots of large trees, bamboos and banana stumps (Short *et al.*, 1930). In the course of investigations made in the cutaneous leishmaniasis endemic area of Aurangabad dt., U.P., India, Farook & Outubudeen (1945) searched all possible breeding places and found only 2 sandfly larvae from soil, obtained from a cow shed. In USSR larvae of *P. papatasi* were found sparsely in rodent burrows (Dolmatova & Demina 1971). In Saudi Arabia Buttiker and Lewis (1979) collected an average of 6.2 *P. papatasi* larvae per rodent burrow. In 1980 Pandya and Niyogi collected immatures of *P. papatasi* from cattle sheds and human dwellings. From an area of Sardinia where both visceral and cutaneous leishmaniases occur, sandfly breeding was detected inside an abandoned building of cement blocks (Bettini *et al.*, 1986). Kalra and Ranq (1986) in India found that *P. papatasi* usually breed in floor cracks, embankment areas, forts, monuments and bird tunnel etc. Forest soil, burrows, leaf litters, cracks and crevices, tree bases, animal burrows and termite mounds are found to be the major breeding habitats (Kalra *et al.*, 1986).
Pringle (1952) described in detail the ecological conditions such as soil, water level, soil cracks and salinity influence the breeding of *P. papatasi*. When the soil samples were analyzed from these places, Bettini and Melis in 1988 observed that soil texture, pH, calcium carbonate, organic matters and water content showed no correlation with the number of sandflies that emerged from these places. But they confirmed that the pre imaginal stages of *P. papatasi* are always associated with a relatively stable, cool and humid environment protected from sunshine and rain.

Literature available on the sampling of immatures of sandflies is also scanty. Immatures of sandflies were first sampled plentifully in the new world by Hanson (1961), who obtained a total of 2,258 larvae and pupae of sandflies from site of Panama canal zone by sugar floatation method. Hati et al. (1982), developed a method which is more practicable to detect the immatures of sandflies in nature. When the scrappings from cattle shed were put in small earthen pots and placed on moist sand bed, he observed the emergence of sand flies after a period of a month.

The seasonal prevalence of sandflies has also been worked out by many workers. The occurrence of sandflies in human dwellings was reported by Zivcovic and Miscevic (1972) from South-east Serbia. They also reported that phlebotomine sandflies were found to be associated with various underground shelters in this country. The resting habits
of sandflies at different heights was studied by Abul Hab & Al Baghdadi in Iraq (1972) and they observed that in cotton fields sandflies were seen to rest up to a maximum height of 40 cms. They also studied the seasonal activity of P. papatasi. This species was found to be the predominant species and showed its prevalence from late March to the end of November with a small peak in April to June and a much higher peak in September and October. The distribution of P. papatasi in the settlements of Krishiskaya Stepp was studied by Rasnitsevna and Dergachev (1977) in 1968-72 in an area between the river Kashkadarya in southern Uzbekistan and the river Amu-Darya in eastern Turkmanbia (Soviet Union). Changes in the population density of sandflies in the Serbia, Yugoslavia was studied from 1947-1969 by Zivkovic (1974). Over that period the number of Phlebotomines declined particularly in villages where the standard of living had increased markedly, paying greater attention to hygiene coupled with the use of insecticides were attributed as the causes. The distribution pattern of Phlebotomines in the colonies of great gerbils of Uzbekistan was studied by Dergacheva and Zherikhina (1980) and they investigated that P. papatasi was more abundant. They also suspected that the population may spread further into areas of warmer soils if the areas were irrigated. Recent investigation carried out by Rutledge & Ellenwood (1975) employing emergence traps in suspected breeding places yielded 13 species of sandflies. When sandfly population was examined in the coastal resort city of El Agamy, Alexandria governorate, Egypt, P. papatasi was observed from April to
December with highest density between June and October (Beier et al., 1986). P. papatasi was found to be the predominant species present in all settlements and it was more numerous in natural habitats close to human settlements than distant ones. Moreover they were common in older settlements than in newer urban type. When the distribution pattern was studied, this species predominated in areas characterized by consistently high levels of ground water with moderate soil temperature.

Seasonal occurrence and resting habits of P. papatasi studied by Abdul Hab and Al Baghdadi (1972) showed that P. papatasi was found to occur both outdoor and indoor with two peaks, a minor during May and a major during September and October.

The peak in the prevalence of P. papatasi was shown to be from April to November, when Adler and Theodor (1926) studied the sandfly fauna from Jericho. They obtained 3,850 sandflies of which 3,624 were females of P. papatasi. During December it was not visible in room but a smaller number could be driven out from cracks in walls. Longitudinal observations have been conducted in Isfahan and in Khuzestan to determine the seasonal abundance of sandfly. Nadim et al. (1968) showed that P. papatasi from rodent burrows in Ali Abad village, Isfahan, exhibited two peaks, in June and August respectively with a depression in July. Hussein and Behbehani (1976) recorded P. papatasi in Kuwait and reported that the population was prevalent
in residential areas all along the gulf coast throughout the year.

In Assam, India sandflies were absent during winter months and more in summer months of May or June with a highest density just after monsoon, i.e., August - October (Napier & Smith, 1926). The same trend was noticed by Mitra during 1959 in Kashmir and by Sanyal et al. (1979) in Bihar. This trend shifts in Gujarat, where Pandya et al. in 1977 recorded highest density in April, while Modi et al. in 1978 reported in July at Poona. In southern and eastern India, sandflies were found to occur throughout the year; all along the coast from Bengal to Kanyakumari. The density of sandflies was high during cooler months with high relative humidity i.e., February and March and the number decreased when the temperature increased and humidity declined (May and June) in Tamil Nadu, (Shanmugam et al., 1977). In 1982, Dhanda et al. when studied the density of P. papatasi in different seasons they observed that the prevalence of this species was seen throughout the year in Bihar. The density remained high during April to October and it declined from November to March. Rahman et al. in 1986 found that large populations of sandflies occur in Nilgiris, Tamil Nadu.

Sandflies were reported to rest in a variety of habitats such as cracks and crevices, soil fissures, rodent burrows, tree trunks, termite mounds, caves, bird tunnels, earthen mounds, under stones and foliages, canopies, village settlements, hamlets etc. In Central
Iraq P. papatasi was recorded from both indoor and outdoor (Pringle, 1956). Mesghali (1963) had also reported that P. papatasi was endophilic in behaviour as it was found indoor. Morsy and Shoura (1976) surveyed different habitats such as stables, chicken house, rodent burrow and cracks in desert and in houses in Saudi Arabia and found that P. papatasi was more abundant in houses. P. papatasi was reported to be a domestic species by Jawadian et al. (1977) in Iran.

In the Rajasthan desert, vector of cutaneous leishmaniasis was found in rodent burrows (Sharma et al., 1973). Bird tunnels were found to shelter P. papatasi in Haryana (Kalra et al., 1986). While P. papatasi was found to be more predominant in human dwelling, P. argentipes was common in cattle shed in Poona (Modi et al., 1978). Similar such observation was noticed by Das and Mukherjee (1969) in Calcutta.

During 1977, Modi had reported in Bengal that P. papatasi was common in houses and rare in cattle dwelling. During an epidemic in Bihar, Kaul et al. (1979) found that P. papatasi was more endophilic and contributed 60% of the total sandfly fauna, when captured. Sandflies in Bihar were mostly seen resting on lower parts and corners of mud walls of houses (Sanyal et al., 1979) indicating that only a partial spray is necessary and the whole house need not receive a spray.
The biology of *P. papatasi* under laboratory conditions was studied as early as in 1922 by Whittingham and Rook and they reported that *P. papatasi* completes the life cycle within 25 to 28 days. Dolmatova (1942) reported that single blood meal was sufficient for egg maturation. He assumed although death at oviposition was invariable in the laboratory it was obvious not usual for vector species, which must feed at least a second time to transmit an infection. Dergacheva, (1970) studied the fecundity of *P. papatasi* in Uzbekistan. Under laboratory condition death during oviposition in sandflies was reported by Killick & Kendrick (1978). The same author also found out that *P. papatasi* took more than one blood meal during single gonotrophic cycle in 1983. Schlein *et al.* (1984) carried out an investigation in the laboratory and demonstrated that the engorging female *P. papatasi* secreted out pheromone on to the host skin while feeding. Feeding behaviour was studied by Schlein and Warburg in 1985 and they found that more females were seen to feed at night than during the day.

Modi and Desh (1983) developed a simple technique for mass rearing *P. papatasi* in the laboratory. The mating behaviour and occurrence of polygamy were reported by Yuval and Schlein in 1986. When the life cycle of *P. papatasi* was observed by Pandya (1980) he noticed that this species completed the life cycle within 39 - 45 days.
In West Bengal sandflies were found to undergo at least 4 gonotrophic cycles in nature (Hati, 1983). His finding indicates that 34.09% of female flies could lay eggs and take blood meals, the probability of taking blood meals and laying eggs reduced as time pass and the bi-parous, tri-parous and quadri-parous percentage of flies was 12.69, 4.56 and 0.57 respectively.

Diapause, a state of developmental arrest which helps an insect to withstand adverse environmental conditions is believed to exist in sandflies. In temperate countries, sandflies overwinter as egg or larvae. It can occur in any stage (Killick-Kendrick, 1983). Theodar (1934) investigated that unfavourable conditions such as lack of food, over crowding, low temperature are responsible for diapause.

Gonotrophic cycle of P. papatasi was studied by Magnarelli, et al. (1984) and they observed highest mortality during oviposition. Gonotrophic relationship was also studied by El Said et al. during 1985 in P. papatasi and they reported that this species was gonotrophically discordant.

Autoeny has been reported in P. papatasi by Dolmatova (1946). Kammah (1972) also studied the frequency of autoeny in wild caught P. papatasi in Egypt and he demonstrated that autogenous females of P. papatasi produce fewer eggs than blood fed individuals.
Several sampling devices have been utilized and their efficacy and suitability for different situations have been critically assessed by Rioux et al. (1967) and Croset et al. (1977). The methods include hand capture, man bait capture, sticky paper trap, sticky paper lit with a torch light, light trap with carbon-di-oxide and new jersey light trap. The breeding places of sandflies were explored by emergence traps. Buttiker (1979) devised an improved method for sampling sandflies by using transparent hard plastic sheet covered with caster oil on both sides, lit with a torch on one side. When he was comparing the catches obtained by adhesive papers without light, adhesive cards with light and the hard plastic sheets with light, he observed that the last one was the best among the three and the yield per sheet was 5.2, 24.7, and 45.0 respectively. The advantages of the plastic sheets in withstanding climatic changes were also discussed. Collections of sandflies were made by means of funnels and by adhesive paper traps near houses and cultivated fields. Bettini et al. in 1986 obtained 3,841 sandflies by using emergence traps in Sardinia. Sukkar et al. 1982 found a higher proportion of gravid females from burrows of rodents and some carnivores by adhesive paper funnel in Iraq.

Quate in 1964 described the flight pattern of sandflies as a series of short, erratic hops. As early as 1914, Prince computed 270 mtrs. as the flight range in Assam. The distance was calculated from
the places of bites to their breeding places. Young (1923) estimated the range as not more than 90 mtrs., for P. papatasi in Peshawar. Soviet workers estimated that this insect may sometimes move as far as 1500mt. but this distance was not achieved by qorged or gravid females (Killick-Kendrick, 1983). Anderson (1939) observed that they are capable of flying as high as 70 feet above the ground level. Employing a mark/release/recapture method Smith in 1936 found that the dispersal range was around 45 mtrs. He also observed the influence of wind on dispersal and concluded that strong wind was not conducive for flight.

Sugar feeding is more frequent in sandflies and even before blood meal they were seen to feed on plant sap and sugar (Lewis & Domoney, 1966). Plant sugar is regarded with a new interest since it was a reported that the leishmanial promastigotes developed in the sandfly gut only when sugar was present. This was indirectly proved by Swaminath et al. (1942) when they carried out a transmission experiment under laboratory condition. In the laboratory they were seen to feed on sucrose and plant sap when provided. Schlein and Warburg (1986) studied the preference of plant sap by P. papatasi and observed that this insect fed on 8 out of 19 plant species tested in the laboratory in Israel.

P. papatasi was reported to be adapted for nocturnal mode of life. The diurnal activity of sandflies was observed by Remyannikova
(1977) from Turkmenia. Mohsen (1983) reported that the activity starts after sunset and ends before sunrise with a highest peak activity after midnight. It began entering houses directly after sunset. He also studied the biting activity physiological age and vector potential of *P. papatasi* in Central Iraq. Ingress of *P. papatasi* estimated was 17% before 23.00 hr. and 83% from 23.00 hr. to sunrise (Sherif El Said et al., 1986) in Egypt. Pringle (1957) studied the relationship between temperature and biting activity of sandflies in Iraq. When he tried to estimate the biting rate of *P. papatasi* with temperature he observed the following results. The biting rate (no. per man-hour) was 23 at 21.0 - 23.9°C, 3-13 at 23.9 - 26.7°C, 0-21 at 26.7 - 29.4°C, 0-5 at 29.4 -31.0°C and there was no biting at temperature above 31.0°C.

Extensive literatures are available on host feeding pattern of *P. papatasi*. In 1925 Lloyd et al. found that in Calcutta *P. papatasi* had shifted to anthropophilic from zoophilic to a greater degree. Later Lloyd and Napier (1930) reported that *P. papatasi* was more anthropophilic in West Bengal. Ponirovski (1968) reported that *P. papatasi* preferred human blood in Turkmenia, USSR. Zivkovic and Mischevic (1971) also found that *P. papatasi* was anthropophilic.

From Aurangabad district, Maharashtra State, Dhanda and Modi (1971) gave the results of precipitin tests of blood meal smears of sandflies. Of 463 blood smears obtained from *P. papatasi* the
proportion that gave positive reaction for man, bovid and other domestic animals was 95.3%, 2.2% and 2.3% respectively. In Gujarat, Dhanda and Modi (1971) observed that this species was mainly zoophilic. In 1972 Pandya et al. identified the blood meal of sandflies by Ouchterlony gel diffusion method and found that majority of the P. papatasi was seen to be fed on bovine blood. Zivkovic et al. (1973) employed agar gel double diffusion test to determine the blood meal of P. papatasi. When the blood meals were tested, they showed positive to human blood, horse, pig, sheep, dog, and cow and none was positive to fowl blood. A survey was conducted during 1977-78 for blood meal analysis in Surat by Pandya (1979) in which 18 out of 26 P. papatasi showed positive towards human blood. In 1982 it was observed that in Maharashtra P. papatasi was mainly anthropophilic while P. argentipes was zoophilic (Dhanda et al., 1982). They also reported the occurrence of mixed blood meal in P. papatasi. The occurrence of double blood meal was also reported by Dhanda and Gill in villages of Maharashtra (1982) in P. papatasi. From these results the authors concluded that in their study area, P. papatasi was anthropophilic. Pandya (1985) reported mixed blood meal in P. papatasi from Gujarat. In his observation 72.34% of P. papatasi had double blood meal and 8.5% had triple blood meal. Mukhopadhyay and Chakravarthy (1987) from north Bihar investigated the blood meal of P. papatasi using ouchterlong gel diffusion technique and reported that 73.7% showed positive for human blood, 4.1% for avian blood and 2.9% towards murine blood.
When Javadian et al. (1977) tested 575 blood smears of *P. papatasi*, the proportion giving reaction for human blood was only 12.5%, while the proportion positive for chicken, pigeon, cows, mule and sheep was 43.5%, 10.4%, 8.5%, 11% and 2.8% respectively.

To determine the physiological age there is no reliable and rapid method. Age grouping of sandflies utilizing the criterion of the presence of granules in the accessory glands was attempted by Chaniotis and Anderson (1967) in the course of their study on the fauna of Fars Province, South Iran. Lewis et al. in 1970 also recognized the parous flies by the presence or absence of granules in the accessory gland in certain species of sandflies. The attempts made by Mohzen (1983) to find out the age of *P. papatasi* employing secretions in the accessory glands was found to be unsuccessful, despite it is possible in other sandflies which are non-autogenic. Dissection of ovaries to find out dilatation is difficult as the ovary is delicate (Killick-Kendrick, 1978). In few species of sandflies it is possible to estimate the number of gonotrophic cycles of a female by examining relics on the ovariole stalks (Gullvard et al., 1981). Follicular development and parity status of *P. papatasi* was studied by Magnarelli et al. (1984). They distinguished the parous females from nulliparous by dilatations. Yuval and Schlein (1987) developed a technique for determining the age of *P. papatasi* by counting the daily growth layer of skeletal apodemes in Israel. Ashford (1974) noted that in 0.7% saline parous females tend to sink
and nulliparous females float.

Many reports are available on the susceptibility of *P. papatasi* to different insecticides. While this species was reported to be resistant to DDT in India (Joshi et al., 1979), it was found to be susceptible to DDT in Uzbek, SSR, USSR (Dergachev and Strelkova, 1986). When diazinon was sprayed in Saudi Arabia total mortality of *P. papatasi* was observed (Buttiker, 1980).

Literature on the population dynamics of sandflies is scanty. Disney (1968) made observations on the dynamics of sandfly in British Honduras. Population fluctuation of sandflies in different seasons was also observed by Shaw and Lainson (1972) while studying the relationship between leishmaniasis and sandflies in Brazil. Rutledge et al. (1976) also studied the dynamics of sandfly population in Panama, employing a wide variety of techniques.