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Ecology and Biology of Phlebotomine Sandflies (Diptera: Psychodidae) in Different Leishmaniasis Foci in the Jenin District, West Bank, Palestine

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TO

MY DEAR FATHER, MOTHER, BROTHERS

SISTERS AND FRIENDS FOR THEIR

ENCOURAGEMENT, WITH LOVE AND

RESPECT

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Abstract

Leishmaniasis is one of the important health problems in the West Bank, Palestine. This study was carried out in the Jenin district, where the most important foci of leishmaniasis in the West Bank during the last decade were occurred. The sandfly fauna of the area is unknown. Light traps, sticky traps, Knock-down and human-landing collection techniques were used to investigate the sandflies of the area and to give base line guidance on various aspects concerning sandfly ecology to further studies on the sandfly of the district.

A total of 4082 sandflies had been collected from different foci of cutaneous (CL) and / or visceral (VL) leishmaniasis during the period from June to December 1998. Thirteen species and seven varieties belonging to seven subgenera of the genus *Phlebotomus* and *Sergentomya* had been found in the district. These include *P. (Larroussius) perfiliewi transcaucasicus, P. (L.) tobbi, P. (L.) mascittii canaaniticus, P. (L.) mascittii mascittii, P. (L.) major syriacus, P. (Phlebotomus) papatasi, P. (Synphlebotomus) sp., P. (Paraphlebotomus) sergenti sergenti, P. (Pa.) jacusieli, P. (Adlerius) halepensis, S. (Sergentomya) theodori, S. (Sergentomya) fallax, S. (Sintonius) tiberiadis, S. (Sintonius) christophersi.* In addition to two other subspecies, *P. (L.) major major, P. (L.) major neglectus*, which require further investigation, were collected. Of the above-mentioned species seven could not be excluded as possible vectors of leishmaniasis, indicating the high risk of infection with leishmaniasis in the district. *Phlebotomus papatasi* was considered the most probable vector of CL in the area because it had a high density in the surveyed human habitats especially from indoor environment of patients of CL. Moreover it was the main human-biting species found in the area. The most likely vector of VL was *P. m. syriacus*, as it was found in large numbers in animal shades, and it fed both on human and most probably animals. This is the first time that the subgenus *Synphlebotomus* reported from the West Bank and neighboring countries.

Among the five species of sandfly collected on human bait, *P. papatasi* was the most abundant constituted about (90 %) of the sandflies collected, followed by *P. major* (8 %) while the other three species *P. tobbi, P. mascittii, and S. theodori*, constituted (2 %). Sandfly human-biting activity occurred through the night and it was highest within 3-4 hours after midnight.

Two female sandflies, *P. papatasi* and *P. sergenti*, were found infested with mites and one female of *P. papatasi* was found infected with nematodes. Sandflies species collected in this study were described and illustrated.

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 Overview

Phlebotomine sandflies are small, tiny, night flying blood-sucking insects, generally, occurring in warm and temperate regions. Phlebotomine sandflies are widespread in the West Bank, Palestine, where they are called "sockatteh or sochatteh" (=noiseless flight insects) because of its silent flying. The same name is also used in Saudi Arabia (Buttiker & Lewis, 1983).

Phlebotomine sandflies are important vectors of many human diseases including four main forms of leishmaniases: visceral (VL), cutaneous (CL), muco-cutaneous, and diffuse cutaneous leishmaniasis; sandfly fever (Three-day fever), Bartonellosis (Oroya fever); in addition to nuisance caused by them (Lane, 1993).

Sandflies have gained significant importance as the principal vector of leishmaniases, caused by parasites of the genus *Leishmania*, with disfiguring or fatal consequences threatening 350 million people in the world, 12 million of these people are already infected (WHO, 1993).

In the West Bank, two forms of leishmaniasis, VL and CL are found. Both forms are endemic to the area, and neighboring Israel (Greenballt *et al.*, 1985). Where It had been considered as a public health problem of considerable importance in this area during the last two decades (Arda, 1983; Klaus *et al.*, 1994; Qubain *et al.*, 1997; Benth *et al.*, 1998).

Huntemuller (1914) was the first to record cases of CL in the Jordan Valley. Interest in leishmaniasis had increased during the British Mandate in Palestine (1916-1948). During that time, CL was highly endemic in Jericho and Dead Sea area, and few cases of VL, most of them in lower Galilee, had been reported (Adler, 1964). A few records were made about leishmaniasis between the late 1948 and 1960's. However, 502 cases of CL were reported from 1960 to 1975 (Greenballt *et al.*, 1985). Also 45 cases of "infantile" VL, all of them were Arab children from western Galilee, were reported during 1960-1969 (Freundlich & May, 1972).

In 1978, Blum described a new endemic focus of CL in Salfet town. Arda (1983), diagnosed 237 cases of CL from different districts of West Bank during 1972-1980, 55% (131 cases) from Salfet district and 14% (33 cases) from Jenin district. A total of 242 cases of CL and 2 cases of VL were reported from March 1983 to September 1989, from different districts of West Bank, 40% (97/242) of the CL cases were from Jenin district (Arda & Kamal, 1989). The exactly number of VL cases during 1970s and 1980s in Israel (including Palestinian Territories) is not known. However, 63 cases of VL were reported between 1970 and 1989 (Oren *et al.*, 1991).

In the West Bank, during 1960s and before, sandflies were not a considerable human biter. The sandfly was not therefore well known to residents in rural areas where people are more exposed to insect bites. This rarity of sandflies in domestic areas in 1960s may be due to heavy smoke generation, all the night, from animal manure incineration which was used as a source of energy for bread baking and other cooking purposes. This process was not only a repellent to sandflies and other insects, but it also eliminated

animal manure, an important breeding site, from human habitat. The presence of different types of domestic animals very close to human, in all houses, provided sandflies with different sources of blood meals. The use of insecticides, especially DDT, for malaria control in some areas, may have contributed to the rarity of sandflies. Ecological changes that occurred in human habitats during the last three decades have had significant effects on sandfly ecology and consequently their role in disease transmission.

In the last nine years there has been a tremendous increase of the leishmaniasis cases in West Bank. A total of 1228 CL and 127 VL cases were recorded, of these 461 CL cases (37.5%) and 50 VL cases (39.3%) were encountered in Jenin district (Sawalha S., unpublished work; Ministry of Health, unpublished statistical reports, 1989-1999).

Despite the increase of leishmaniasis cases in the last decade in the West Bank, especially in Jenin district, epidemiological studies on the epidemiology of the disease, especially on the ecology of sandflies and reservoir animals are lacking. Such studies are essential for the understanding of epidemiological cycles and for the development of control strategies to reduce transmission of the disease, because vector control is considered to be the main method for prevention and control of the disease (WHO, 1984).

Basic information on sandfly vectors of leishmaniasis in the West Bank is almost lacking, as most studies on sandflies were concentrated in the Jordan Valley. The present study was therefore, carried out to obtain adequate data on some ecological aspects of sandflies in Jenin district, where leishmaniasis cases increased during the last decade, in order to help in disease control and

to provide a base line for guidance to further studies aimed at exploring the role of different sandfly species as vectors of leishmaniasis.

Furthermore, Lewis (1982) stated that "VL and CL usually occur in different areas largely owing to the distribution of their vectors". In Jenin district both form of the disease are found in some localities even in neighboring houses (Abdeen *et al.*, In preparation). Studying the ecology and biodiversity of sandflies would be of a significant importance for understanding of the epidemiology of these diseases.

1.2 The Phlebotomine Sandflies

1.2.1 Biology of Sandflies

Although different Phlebotomine sandflies species occur in various countries and have some features in common they are different to some extent in appearance and biology. Differences in biology include life cycle, feeding, dispersal, and other activities. Such differences have an effect on the epidemiology of leishmaniasis and vector control (WHO, 1990).

1.2.1.1 Distinguishing Features

Sandflies are distinguished from other bloodsucking Diptera by their small size (1.5-4 mm), long slender legs, hairy appearance, pointed wings held above their body at an angle of 45 degrees, and hopping flight pattern with many short flights and landing. The thorax is markedly humped, and color varies from light yellow to dark gray. In males the terminalia are conspicuous at the end of the abdomen (WHO, 1984).

1.2.1.2 Life Cycle

Little is known about the mating behavior of sandflies in nature and how the males and females communicate. However, males are known to be attracted to hosts on which females may feed (WHO, 1984).

Sandflies have a holometabolous life cycle, consists of four stages, namely egg, larva, pupa and adult. The former three stages are found in soil (Word, 1985). The cycle may last from 1 to 4 months, depending on species, diet and temperature. Sandflies deposit their eggs in humid places on damp soils rich in organic nutrients, such as soil cracks, crevices, animals' burrows, caves and damp leaf litter in forests (Ready, 1979).

A female sandfly lays 50-100 eggs in each oviposition patch. The eggs are elongate with rounded ends, about 0.4 mm in length, and pale in color when first laid, but soon become dark-brown or black. Eggs are very sensitive to sunlight and dryness. Generally, hatching occurs one to two weeks later, depending upon the temperature and species (Ward, 1985; WHO, 1984).

There are four larval instars that feed on decaying organic matter, rotting vegetation, feces of rodents or reptiles, dead insects and other organic materials (Adler *et al.,* 1957). The larvae are very small caterpillar-like creatures (0.5 mm in length), and it is difficult to detect in nature. The duration of the larval stage varies with temperature and season, but on an average it is 35-40 days, excluding diapause period. Diapause of the fourth stage larvae is the mean by which sandflies survive period of unsuitable environmental conditions such as low temperatures, and heavy rains in winter of Palaearctic region (Adler & Theodor, 1957).

When fully grown, the fourth instar larva stops feeding and shows visible thoracic- swelling. The larva attaches itself to the substrate by its terminal segment and eventually moults into a pale colored pupa. The last larval skin is always attached to the end of pupa. The pupa is inactive and usually after five to ten days, it darkens and following some flicking stretching movements the adult emerges during the hours of darkness, often just before dawn (Ready, 1979).

The adult longevity varies considerably. Females may live up to Forty days or longer. Unfed sandflies die on about the forth day after emergence. (Lewis, 1971).

1.2.1.3 Bionomics of Adults

Sandflies are usually nocturnal in their activities, which include host biting, sugar feeding and mating, but behavior patterns differ greatly among species (Lewis, 1971).

1.2.1.3.1 Dispersal

Because of their flight pattern, short hops with many landings, sandflies disperse short distance from their breeding sites for feeding, mating, resting or oviposition (WHO, 1984). Quate (1964) using mark / release / recapture method, showed that most of the flies were recaptured at a distance of about 300 m, except one sandfly caught at 730m. Schlein *et al.* (1982) found that member of *P. papatasi* were attracted to turkeys over a distance of 800 m, and they showed that the dispersal activity of *P. papatasi* in the Jordan Valley was mainly a female activity. However, in open habitat during their nocturnal

activities sandflies may travel up to 2200 m over a period of few days (Killick-Kendrick *et al.*, 1984).

1.2.1.3.2 Feeding habits

Both males and females feed on sugar as a source of energy for flight and other activities. Sandflies reared in the laboratory die within few days without providing them with sugar meals. However, it was suggested that sugar meals play important role in sandflies ecology and epidemiology of leishmaniasis. Because possible preference by sandfly for particular plants may restrict its distribution, consequently the distribution of the parasites it transmits, and the type of sugars and frequencies with which they are taken by a particular species may be a factor in the insects ability to transmit *Leishmania* parasites (Killick-Kendrick, 1978).

Sandflies obtain there sugar meals from aphid and coccid (Moore *et al.*, 1987; Mac Vicker *et al.*, 1990), and ecological evidence showed that aphid honeydew may be a source of sugar for them (Cameron *et al.*, 1995). *Phlebotomus papatasi* feeds selectively on plant and honeydews in the laboratory (Schlein & Warburg, 1986) and was also found to feed on plant tissue in the field (Schlein & Jacobson, 1994 a). However the specific sources of natural sugar meals are unknown (Schlein & Jacobson, 1994 b).

Females of sandflies take blood that is needed for egg development, but males do not. A few species of sandflies are able to lay first patch of eggs without the need for previous blood meal. This phenomenon known as autogany occurred if diet of larvae is rich, resulting in the females emerging with sufficient food reserve to produce eggs without the need for blood meal (Davies,

1988). Some species of sandflies need single blood meal to lay batch of eggs, while other species such as *P. papatasi* may refeed several times without relation to egg laying (Adler & Theodor, 1957); so that refeeding habits are of considerable importance in the transmission of diseases.

Blood is taken from human, animals, birds and reptiles. According to the development of buccal armature and host preference, sandflies are divided into two groups of genera, the first feeding on worm-blooded animals and the second feeding on cold-blooded animals. The former group includes three genera, *Phlebotomus* and *Chinius* in the Old World and *Lutzomyia* in the New World. All other genera of Phlebotomine sandflies are involved in the second group. In the Mediterranean region *Phlebotomus* species feed on mammals, and *Sergentomyia* species feed mainly on lizards (Adler & Theodor, 1957). It had been found that some species of *Sergentomyia* in Sudan bite human regularly (Quate, 1964). Schlein *et al.* (1982) found that *P. papatasi* in the Jordan Valley prefer to feed on blood of turkey rather than the sand rat *Psammomys obesus* near turkey sheds.

However, each species has specific preferences for its source of blood, which it may differ between regions (Adler & Theodor, 1957) but the availability of hosts is an important factor, because the range of sandfly flight is short which limits the choice of reaching to the preferred host(s).

Sandflies are mainly nocturnal in their biting activities, although they are described as crepuscular. In dark rooms, forests, and similar places they may bite in the daytime, especially if distributed by human activities (Rozendaal, 1997). It is possible that each species has its peak hour of biting during night. Wijers *et al.* (1974) showed that the peak of biting activity was from sunset until

about 21:00 hours. Human-beings are generally bitten on the face, hands, arms, ankles and legs, the parts of the body mostly exposed when sitting outdoors or when sleeping without adequate cover (WHO, 1984).

The adult of *P. papatasi,* in Mediterranean region, disappear from the onsets of winter begin in November and reappear in May (Adler & Theodor, 1957).

1.2.1.3.1 Resting places

During daytime, sandflies seek out shelter, dark and relatively humid, but not wet sites for resting, so that, they may be found resting either at indoors (endophilic) or at outdoors (exophilic) sites. Indoor resting-places include dark humid corners and behind clothes, cupboards, pictures etc. (Lewis & Kirk, 1951). While, outdoors resting-places involve a wide range of habitats such as crevices in walls, stone walls, stacks of firewood, bricks, rubbish and other places around human houses. Places used as breeding sites include tree holes, caves, stables, animals' burrows, caves, dugouts, banks of streams, and in cracks and fissures in the soil (Rozendaal, 1997; WHO, 1996).

1.2.1.4 Classification

In 1786, Scopoli described species of *Phlebotomus* sandflies. But interest in the classification of the Phlebotomine sandflies started after its role as a vector of various protozoan and virus diseases was discovered (Forattini, 1973). Newstead (1911) divided sandflies of the Maltese Island into two groups, those of erect hairs on the dorsum of the abdomen, and those with recumbent hairs. Franca (1919) studied the species of *Phlebotomus,* dividing

them into two subgenera *Phlebotomus* and *Newsteadia*, on the characters of the male genitalia. After suggesting various modifications of this system, Franca and Parrot (1921) divided the genus into five subgenera, namely, *Phlebotomus, Prophlebotomus, Brumptomyia, Lutzomyia,* and *Sergentomyia.* This classification was not considered as definitive one, but as a guide to further work and research (Parrot, 1934).

Adler & Theodor (1926 a) showed that the buccal cavity and the pigmented area, as well as the morphology of pharynx and spermatheca were of diagnostic value in the determination of the species. In 1929, Sinton showed that in the species of the recumbent-haired group, the spermatheca has a smooth outline and a buccal armature is present, while in species of erect-haired have segmented spermatheca and the absence of buccal armature. So that he divided the genus *Phlebotomus* into three main groups namely, Erect-haired Division, Recumbent-haired Division, and Intermediate Division.

Later classification emphasized on the buccal cavity as of greater value than the abdominal hairs. Theodor (1931) divided the genus *Phlebotomus* into two primary divisions: species, which possess a buccal cavity with, pigmented area and those without a buccal cavity and no pigmented area. Nitzulescu (1931) divided the genus into five subgenera: *Sintonius, Brumptius, Larrousius, Phlebotomus, and Adlerius*, by using buccal cavity, cibarium teeth, pigmented area, and spermatheca shape. Parrot (1934) divided the genus into two subgenera: *Phlebotomus* and *Prophlebotomus,* and he pointed that Nitzulescu's scheme relies almost solely on female characters, taking no account of the male genitalia.

Theodor (1948) proposed an elaborate classification of sandflies, he recognized two genera in the Old World, *Phlebotomus* and *Sergentomyia*, corresponding with the subgenera *Phlebotomus* and *Prophlebotomus* of Parrot (1934). The first genus is divided into nine subgenera: *Phlebotomus, Paraphlebotomus, Synphlebotomus, Larroussius, Adlerius, Euphlebotomus, Anaphlebotomus, Australaophlebotomus,* and *Spelaeophlebotomus,* and the second genus is divided into three subgenera: *Sergentomyia, Sentonius* and *Spelaeomyia.* Theodor (1958) grouped the sandflies of the world in three main genera *Phlebotomus* Rondani, *Sergentomyia* Franca and Parrot of the Old World and *Lutzomyia* Franca of the New World.

Increasing awareness of the medical importance of sandflies as a vector of protozoan and viral diseases has led to renewed interest in the classification of the Phlebotomine sandflies (Forattini, 1973).

A little is known about the variation in Phlebotomine sandflies. Two aspects of the subject important to mention, abnormality such as variation in size and shape of pigmented area (Lewis & Kirk, 1951), and geographical races, because its delicacy and limited power to fly.Phlebotomine sandflies have a marked tendency to develop local races and varieties (Theodor, 1933).

Phlebotomine sandflies belong to the order Diptera, family Psycodidae, subfamily Phlebotominae that comprises about 700 species and subspecies (WHO, 1984 and Lane 1993). These species are grouped in six genera, *Phlebotomus, Sergentomyia* and *Chinius* in the Old World, and *Lutzomyia, Brumptomyia*, and *Warileya* in the New World (WHO, 1990). Species and subspecies of *Phlebotomus*, *Lutzomyia* and *Sergentomyia* suck blood from vertebrates. About 70 species and subspecies of the former two genera involve

the more medically important sandflies as they include leishmaniasis vectors, and thought to be involved in the transmission of other diseases to man (Lane, 1993; WHO, 1984).

1.2.2 Medical Importance

Phlebotomine sandflies bites cause irritation and sometimes extreme discomfort, as well as, because of their anthrophagic behavior, they transmit diseases. The symptoms of sandflies bite and the mode of transmission and symptoms of some sandflies-borne diseases are described below.

1.2.2.1 Nuisance

Sandflies bite can cause a serious but localized biting nuisance and produce an irritating itching restricted to the parts of the body exposed to sandflies bites, which is similar in appearance to chickenpox. Persons newly exposed to bites of sandflies often experience a severe urticarial reaction known as "harara" in Israel (Adler & Theodor, 1957).

1.2.2.2 Sandfly fever

Sandfly fever, also known as three-day fever and papataci fever, is acute fever of three days hyperpyrexia, caused by a virus transmitted by *P. papatasi.* It is well known in the Mediterranean region and thought to occur throughout the Old World (Lane, 1993). Cases occur between April and October during the sandfly season (Adler & Theodor, 1957); during diapause period the virus persists in the larvae.

1.2.2.3 Bartonellosis

Bartonellosis, also known as Oroya fever, is acute, sometimes, fatal rechettsial disease caused by *Bartonella bacilliformis*. It is transmitted mechanically by contamination of the parts of mouth of sandflies. The sandfly vectors include *Lutzomyia verrucarum* in Peru and Ecuador, and *Lu. colombiana* in Colombia. The disease is encountered in arid mountainous areas of Andes (Lane, 1993).

1.2.2.4 Leishmaniases

Leishmaniases are a complex of diseases caused by single-celled protozoan parasites of different species of the genus *Leishmania* (Protozoa, Trypanosomatidae). The parasites are transmitted from animals to humans and from human to human, by Phlebotomine sandflies, which are the only probably known vectors (WHO, 1984).

The parasite occurs in man and other vertebrate animals in an amastigote form (no free flagellum) in the reticulo-endothelial tissue of the skin, spleen, liver, bone marrow, and lymph nodes and may invade other tissues in other organs. When ingested by a female sandfly, the amastigote form transforms and multiply in the gut as a promastigote (single free flagellum) Which then changes into a metacyclic form (Bates, 1994). The disease is widely distributed and appearing in four main forms VL, CL, muco-cutaneous leishmaniasis, and diffuse cutaneous leishmaniasis (Lane, 1993).

Visceral leishmaniasis also known as Kala-azar, is a disease of internal organs, the parasite invades the cells of spleen, bone marrow and liver. It is usually fatal in the absence of correct diagnosis and treatment. (WHO, 1984). It

caused by *Leishmania donovani* or *L. infantum* in the Old World, and *L. chagasi* in the New World. In Latin America alone there are about 16000 cases annually, and 1.6 million people were threatened (Ashford *et al.*, 1992).

The disease is characterized by irregular rounds of fever, substantial weight loss, swelling of the spleen and the liver and anemia (WHO, 1990). It is endemic in East Africa, the Indian subcontinent and South America, and occurs sporadically in the Mediterranean region, southwest Asia and the southern part of USSR.

The CL, also known as oriental sore, Aleppo boil, Jirecho boil in Palestine, and other common names, normally produces skin ulcers on the exposed parts of the body. *L. major, L. tropica, L. aethiopica* in the Old World, *L. baraziliensiss* and *L. mexicana* in the New World cause it. Atypical ulcer starts as a nodule on the exposed part of the body; a crust develops in the middle that when falls away exposed the ulcer. CL is the common form of leishmaniasis and occurs in Africa, South America, the Indian subcontinent, Mediterranean region, south-west Asia and southern parts of the USSR (WHO, 1990).

Mucocutaneous leishmaniasis is a severe disfiguring disease caused by *L. baraziliensis* and *L. panamensis* invading and eroding the cartilaginous tissues of the nose and plate. Most of the cases occur in South America (WHO, 1984).

1.2.2.4.1 Leishmaniasis Control

Methods used for leishmaniasis control are determined by the ecology of the disease. According to their ecology leishmaniasis can be divided to,

anthroponotic leishmaniasis with man as the source of infection, and zoonotic leishmaniasis, with wild animals as a source of infection. So that, theoretically there are four groups of measures for the control of leishmaniasis which can be used separately or in integrated form. These measures include treatment of the cases, especially where man is the reservoir, control of the source of infection (reservoir animals), control of the vector and protection of people (Vioukov, 1987)

1.2.3 Sandflies Control

Vector control is considered to be the main method for prevention of leishmaniasis. Methods used for sandflies control can be grouped as chemical insecticide, genetical, biological control and ecological measures. Of these methods insecticide application in domestic areas is the most effective one (Lane, 1993).

It is widely recognized that the application of insecticides against adult sandflies is the principle method used in sandfly control. Control of larvae is often impossible, as the breeding sites of most vectors are either unknown or inaccessible (WHO, 1984). Knowledge about habits of the sandflies species that found in certain area is of considerable importantance in control measures; spraying the inside surfaces of walls and the opening of the houses with residual insecticides can control indoor-resting sandflies (Rozendaal, 1997). Antimalaria spraying campaigns led to reduction of VL, CL, and sandfly fever in India, Italy, Greece, USSR, and Israel (WHO, 1991).

Biological agent tested to control sandflies includes, using of *Bacillus thuringiensis* var. *israeliensis* toxin for adult sandflies control (Yuval & Warburg,

1989) which has a significant effect for killing sandflies at a relatively low concentration.

Sandflies may be infected with nematodes. Lewis (1967) found larval parasite, large nematode, in three species of sandflies collected from different parts of Pakistan, these include *P. papatasi, P. sergenti* and *S. clydei.* It is believed that these parasites survived into the adults and killed them. Buttiker & Lewis (1983) found similar parasites in nine sandflies, including three species, *P. sergenti, S. christophersi* and *S. clydei*, collected from Saudi Arabia.

Although sandflies infested with mites that may be harm and may cause killing to eggs, larvae, pupa and adults (Vyukov, 1980). Schlein found three different species of these mites on *P. papatasi* collected from Palestine (cited in Buttiker & Lewis, 1983); and in Saudi Arabia a total of 188 mites classified to four families and\seven genera found on 15 species of sandflies (Buttiker & Lewis, 1983).

In West Bank, an organized campaign to control sandflies, as apart of leishmaniasis control, was started in 1996. The widespread spraying of insecticides such as pyrethroids and residue organo-phosphorous compounds, once a year in all infected areas, were used during sandflies season, parallel to rodents control by using anticoagulants compounds, and stray dogs control by using chemical poisons. Before 1996 the only control measure used was spraying patients' houses, who visited governmental health clinics, with insecticides one to two weeks after their visit (Ramez El Titi, Environmental Health Department, personal communication).

1.3 Sandflies and Leishmaniasis in Palestine and Neighboring Countries

1.3.1 Sandfly Fauna

Studies on sandflies of Palestine, now includes Palestinian Territories and Israel, were started in 1925 by Adler and Theodor who isolated *Leishmania* parasites from *P. papatasi* caught from Jericho (Adler &Theodor, 1926 b).

Y. Schlein (personal communication) caught about one thousand sandflies from different regions of Israel. He found the following species in the northern and central regions, *P. papatasi* (5.1%), *P. sergenti* (36.2%), *P. tobbi* (13.3%), *P. major Syriacus* (21.8), *P. (Adlerius) sp.* (18.9%), *P. jacusieli* (2.8%), and *P. mascitti* (1.9%). The first tree species were also identified in the central Jordan Valley and the southern regions with the following percentage 90.2%, 8.3% and 0.2 respectively, in addition to *P. alexandri* (1.3%) which was found only in this area.

Schlein *et al.* (1982) identified three species of *Phlebotomus* in the Jordan Valley, namely *P.* (*Phlebotomus*) *papatasi* (Scopoli), *P.* (*Paraphlebotomus*) *alexandri* Sinton and *P.* (*Laroussius*) *tobbi* Adler & Theodor. *P. papatasi* was the dominant species. As well as five species of *Sergentomyia*, including *S.* (*Sergentomyia*) *antennata* (Newstead), *S.* (*Parrotomyia*) *africana asiatica* Adler & Theodor, *S.* (*Parrotomyia*) *palestinensis* Adler & Theodor, *S.* (*Sergentomyia*) *fallax* Parrot, and *S.* (*Sergentomyia*) *sinotoni* Pringle.

Lane *et al.* (1988) in their comparison of sandfly fauna in Jordan with neighboring countries mentioned the following species that are reported in

Israel and occupied West Bank: ten species of the genus *Phlebotomus*, including *P. papatasi, P. sergenti, P. alexandri, P. major syriacus, P. jacusieli, P. mascitti canaaniticus, P. tobbi, P. perfiliewi galilaeus* Theodor, *P. halepensis* Theodor and *P. (Adlerius) simici* Nitzulescu; and nine species of *Sergentomya* including *S. antennata, S. fallax, S. theodori* (Parrot), *S.* sp. a, *S. africana* (Newstead), *S. squamipleuris* (Newstead), *S. clydei* (Sinton), *S. tiberiadis* (Adler, Theodor & Lourie) and *S. palestinensis*. The first four and five species of *Phlebotomus* and *Sergentomya*, respectively, were also identified in Jordan (Lane *et al.*, 1988). In addition to *P. kazeruni* Theodor & Mesghali, *S. dreyfussi* (parrot), *S. adleri* (Theodor) and *S. christophersi* (Sinton), as well as two species of *Phlebotomus*, uncertain identification, suspected to be *P. simici* and *P. halepensis.* Also Lewis (1982) reported the first nine species of *Phlebotomus*, in addition to *P. marismortui* Theodor to occur in Israel.

1.3.2 Incrimination of Vectors

Upon investigation of incrimination of sandfly vector(s) of *L. major* in southern Jordan Valley in Jordan, Janini *et al.* (1995) collected 1446 females of *P. papatasi*, and about 50 of *P. alexandri* and *P. alexandri.* None of these flies were infected, but 14 of 686 of *P. papatasi* collected from *Ps. obesus* burrows were infected.

Four females of 3624 *P. papatasi*, caught from Jericho during 1925, were found infected with *Leishmania* parasites (Adler & Theodor, 1926 b). *P. papatasi* was the only species of sandflies found in a focus of CL in Salfit area (Blum, 1978). Schlein *et al.*, (1982) recorded 29 infected out of 70 *P. papatasi* females collected from *Psammomys* burrows or near them in the Jordan Valley.

Yuval (1991) found that 7.4% of *P. papatasi* trapped from *P. obesus* burrows in southern Jordan Valley were infected with *L. major*, more infection were found during July and August, and along the sandfly season. In addition Janini *et al.* (1995) found 14 (of 686) females of *P. papatasi* infected with *L. major* in the eastern part of the Jordan Valley.

Adler and Theodor (1957) stated that the following three species of sandflies *P. major, P. perniciosus* and *P. longicuspis* are probable vectors of VL in the Mediterranean region, and the first one is the only proven vector so far, in the region.

In Israel, it has been found that *P. perfiliewi* is a zoophilic species and rarely feeds on man, and this explain the very low incidence of VL in the area although 20% of dogs were infected during 1930s-1950s (Adler & Theodor, 1957).

1.3.3 Leishmaniasis

1.3.3.1 Cutaneous Leishmaniasis

In West Bank and neighboring Israel there are two types of *Leishmania, L. major* and *L. tropica* that cause CL. *L. major* causes zoonotic CL mainly in the Jordan Valley, where it has been recognized since 1914, when Huntemuller described the first cases of CL. Adler and Theodor (1926 a, 1926 b, and 1927) have proven that *P. papatasi* was the vector of CL in Jericho, Jordan Valley. Naggan *et al.* (1970) and Schlein *et al.* (1982) illustrated that *P. papatasi* in this area has a close ecological relationship with the main reservoir animal of the disease. The sand rat *Psammomys obesus* (Rodentia: Gerbillidae) burrows seem to provide sandflies with moist and relatively cool microhabitat essential

for larva and adults. And this seems to be close to a desert focus of CL in Jordan (Saliba *et al.*, 1985), where most houses of the patients were in peripheral areas. Saliba *et al.*, (1988) isolated *L. major* from human cases and the reservoir animal, the fat, sand rat *Ps. obesus*, in different parts of Jordan.

Further foci of this form of the disease were described. Grender *et al.* (1968) isolated *Leishmania* parasites from *Meriones sp.* trapped in Negev desert, south-western Israel. In the same area Giladi *et al.* (1985) described new focus of CL in Keziot, due to residency of non-immune people in endemic area. The rodents of the genus *Meriones*, and *P. papatasi* were identified as a reservoir animal and vector, respectively. And from Rift Valley also in the southern part of Israel, the rodents *Ps. obesus* and *Mariones crassus* were found to be the reservoir animals and *P. papatasi* the main vector (Greenblatt *et al.*, 1985).

The second causative agent of CL in the area is *L. tropica* was reported in the mountainous area east Jerusalem (Klaus *et al.*, 1994), neither the reservoir animals nor the sandflies vector(s) were identified. Blum (1978) described focus of CL in Salfit area but did not identify the causative agent. Two thirds of the cases occurred in the periphery areas of Salfit. *Leishmania* parasites were isolated from 40% of trapped rodents, *Rattus rattus,* the only species found around patients' houses in the periphery areas. Also *P. papatasi* was the only species of sandflies gathered from these houses. Later, the causative agent of this focus thought to be *L. tropica* (Y. Schlein, personal communication).

A new focus of CL caused by *L. tropica* was reported in Jordan by Kamhawi *et al.* (1995), most of the cases were observed in houses on the

periphery of villages. It is thought that the disease is zoonosis, but the vectors and reservoir animal were not studied.

Arda (1983) and Arda & Kamal (1989) studied the epidemiology of CL in human through West Bank. In recent years, an increase in the number of CL has been observed in different districts of West Bank (Table 1), especially in Jenin district, where 37.5% of the cases have been reported (Sawalha S., unpublished work; Ministry of Health, unpublished statistical reports, 1989-1999).

Table 1. 1 Distribution of reported cases* of CL in West Bank districts in the period between first March 1990 and the end of February 1999.

District	Reporting Year										Total (%)
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	
Jenin	56	27	43	22	50	102	76	20	58	7	461 (37.5)
Jericho	8	22	49	55	51	79	57	36	32	7	396 (32.2)
Nablus	2	6	9	12	56	41	30	16	4	-	176 (14.3)
Tubas	15	3	1	7	23	23	9	-	2	-	83 (6.8)
Hebron	2	-	1	-	1	9	4	6	6	-	29 (2.4)
Beithlehem	-	-	2	-	1	11	5	4	4	1	28 (2.3)
Salfit	3	2	2	3	7	5	2	-	-	-	24 (2.0)
Qalqilia	1	-	1	-	3	3	5	1	-	-	14 (1.1)
Tulkarm	-	1	3	-	-	5	2	-	-	-	11 (0.9)
Ramallah	1	2	-	-	1	1	-	-	-	1	6 (0.5)
Total	88	63	111	99	193	279	190	83	106	16	1228 (100)

*Sawalha S., unpublished work; Ministry of Health, unpublished statistical reports, 1989-1999.

1.3.3.2 Visceral Leishmaniasis

In the Mediterranean region, the VL is a zoonosis occurring in an endemic form, and 80% of cases are children under 5 years old. It is caused by *L. infantum* and transmitted by a number of *P. (Larroussius)* spp. (Killick-Kendrick, 1990). The reservoir animals include dogs, foxes and jackals (Adler & Theodor, 1957).

Jaffe *et al.* (1988) isolated *L. donovani* from 4% of dogs in northern Israel. Qubain *et al.* (1997) isolated *L. donovani s.1.* from an infected child living in a house at the outskirts of a village from Tulkarm district, West Bank. In the central parts between Jerusalem and Tel Aviv 1-11.5% of dogs, 7.6% of jackals and 5% of foxes were found to be infected with *L. infantum* which was also isolated from a child from a village near Jerusalem (Benth *et al.*, 1998).

Fifteen sporadic cases of VL were reported in the West Bank during 1970s and 1980s (Arda *et al.*, 1989). Sawalha (unpublished work) and Ministry of Health, unpublished statistical reports (1989-1999) showed that from March 1990 through February 1999, 127 clinical cases of human VL were reported from all districts of the West Bank excluding Jericho (Table 1.2). Of which many cases (39.3 %) were reported from Jenin district.

Table 1. 2 Distribution of reported cases* of VL in West Bank districts in the period between first March 1990 and the end of February 1999.

District	Reporting Year										Total (%)
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	
Jenin	3	2	2	2	11	14	4	6	4	2	50 (39.3)
Hebron	-	-	-	1	1	4	11	8	7	-	32 (25.2)
Tulkarm	-	1	1	1	4	8	-	1	-	1	17 (13.4)
Ramallah	-	-	1	2	3	3	1	3	2	-	15 (11.8)
Nablus	-	-	-	-	-	2	1	-	-	-	3 (2.4)
Salfeet	-	1	-	-	2	-	-	-	-	-	3 (2.4)
Tubas	-	1	-	-	-	1	1	-	-	-	3 (2.4)
Qalqilia	1	-	-	-	-	-	-	1	1	-	3 (2.4)
Beithlehem	-	-	-	1	-	-	-	-	-	-	1 (0.8)
Jericho	-	-	-	-	-	-	-	-	-	-	0 (0.0)
Total	**4**	**5**	**4**	**7**	**21**	**32**	**18**	**19**	**14**	**3**	**127 (100)**

*Sawalha S., unpublished work; Ministry of Health, unpublished statistical reports, 1989-1999.

1.4 Objectives of the Study

Although many cases of CL and VL have been reported continuously from Jenin district for the last two decades, neither sandflies nor reservoir animal(s) have been identified or studied despite their importance for control measures. Therefore, a general survey is needed to establish base line data.

The present study was carried out to investigate sandfly fauna and some of their ecological aspects in Jenin district, and particularly to provide base line data on the vectors of CL and VL in different leishmaniasis foci in the district.

Thus the present study was aimed at studying:

1. Sandfly fauna and the prevalence of different species in Jenin district;
2. Most prevalent sandfly species of the study area and their distribution especially in foci of VL and CL;
3. Relative density of sandfly species prevalent at different seasons of the year;
4. Main human-biting sandfly species in the area and time of their biting activity;
5. Resting sites of different sandfly species in the area;
6. Effects of some climatic factors on the density of sandfly in Siris village;
7. Degree of endophily and exophily of different sandfly species;
8. Relationship between sandflies and some types of plants and animals in the area; and
9. The efficiency of different sandfly collection techniques used in the study.

CHAPTER TWO

MATERIALS AND METHODS

CHAPTER TWO
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2.1 Study Area

This work was carried out for a period of 6 months, from June to mid December 1998, during the season of sandfly, in Jenin* district (32° 20' N, 35° 8' E), northern West Bank, Palestinian National Authority. Jenin district has 96 localities covers an area of 592 km ² with altitude ranging between 90 and 750 meters above sea level and had a population of 195299 in 1997 (Palestinian Central Bureau of Statistics). It is bordered by Nablus and Tulkarm districts to the south and southwest, Tubas district and the green line (Israel) to the east and north (Figure 2. 1).

Jenin district can be divided into three major topographic areas: the eastern slopes located between Jordan Valley and the central highland; mountain crests (500-650 meters above sea level), form the watershed line and separate the eastern and western slopes; and the western slopes (gentle slopes, 100-400 meters above sea level) (Applied Research Institute, 1996).

Rainfall varies significantly in Jenin district from 778 mm at Um El Rihan station in the west to 286 mm at Raba station in the east and with mean annual rainfall of 528 mm. The district receives rainfall between middle October and end of the April, with peaks in January and February; in March precipitation decreases to 12% of the annual rainfall (Applied Research Institute, 1996).

* Excluding Tubas and surrounding villages, which was considered as a separate district in 1998. In this work samples were collected from the area because it was still refer to by health authority as part of Jenin district.

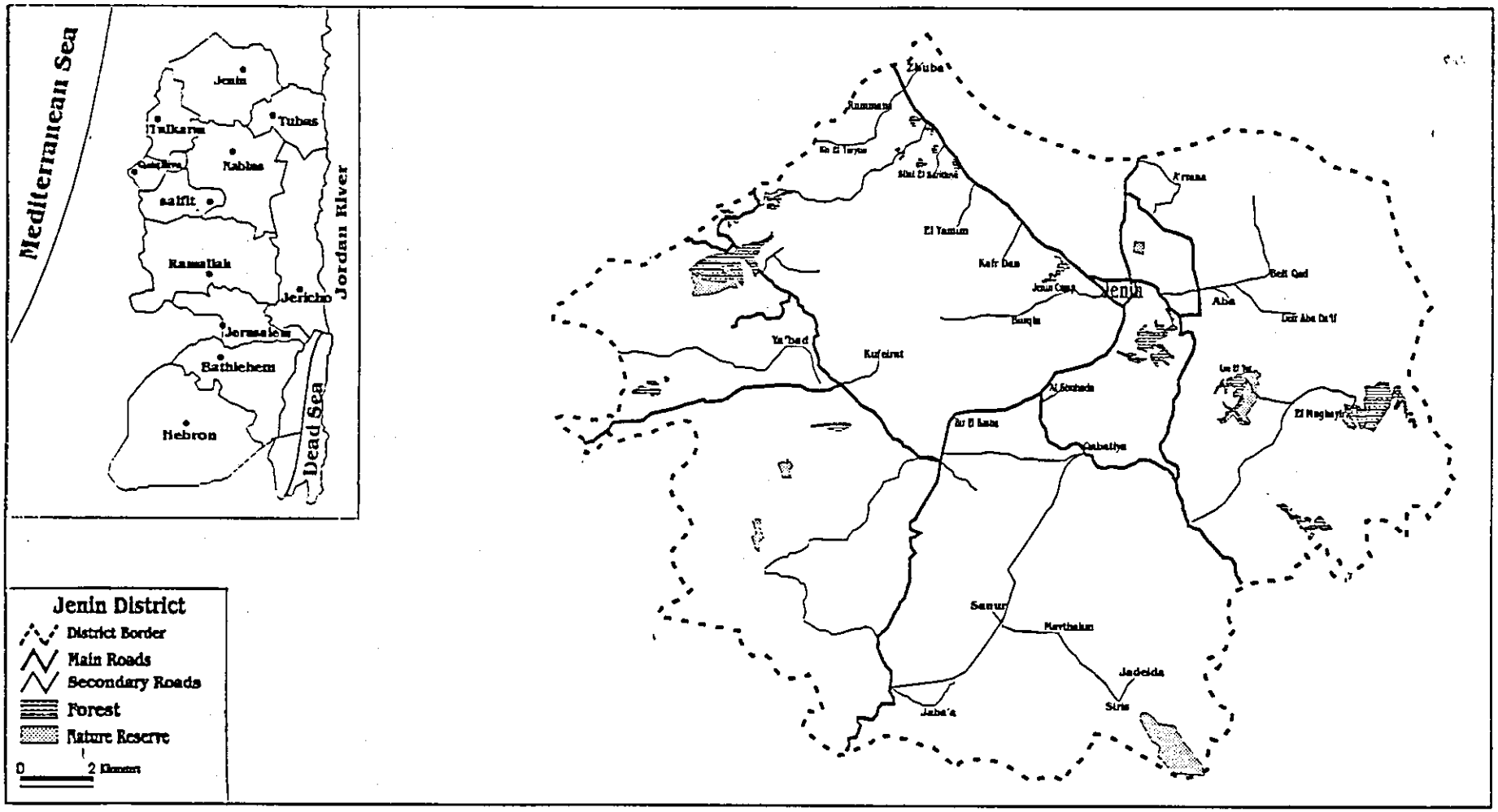


Fig. 2. 1 Map of Jenin district showing the studied localities

August is the warmest month with 34.2° C and 21.1° C as the maximum and minimum temperatures respectively. January is the coldest month of 17.4° C and 6.2° C as the maximum and minimum temperatures respectively (Applied Research Institute, 1996).

Wind blows from southwest and northwest, and being more northerly during the summer. Wind speed increases from April through June, then begins to decrease till October when it increases again. However during summer and winter months the average wind speed ranges between 9.2 and 7.7 km/hour respectively at Bait Qad weather station. There is also a little fluctuation in relative humidity in the district especially during summer months. It ranges from 63 to 66% during June to November, from 67 to 84% during December to April, and it falls to 39% during May as a result of the dry winds that blow from the Arabian Desert.

The soil types of the district include Terra Rossa, Brown Rendzinas and Pale Rendzinas covering 50 % of the area; Brown Rendzinas and Pale Rendzinas covering 30-50% of the soil; Pale Rendzinas covering, small area, and Grumusols found in flat areas (Applied Research Institute, 1996).

The inhabitants mostly work in agriculture, especially in the rural areas that have 60% of the total population. Although raising animals has decreased in the last years, domestic animals like sheep, goats, chickens, and others are still found, nearly, in all localities with different numbers, but the number of poultry houses has increased considerably and especially in certain localities.

Most residents live in houses built of concrete and / or stone. Many of these houses were constructed in the peripheral areas, where most

leishmaniasis cases (70% of VL and 75.5 % of CL) (Sawalha S., unpublished work; Ministry of Health, unpublished statistical reports, 1989-1999).

2.2 Sampling Sites

Sandflies were collected from 23 localities (21 in Jenin district and 2 in Tubas district) out of 36 localities where health authority in Jenin district has been reporting CL and / or VL during 1990 through 1998. The ten localities that were not sampled had 13 cases of CL and 2 cases of VL in the above-mentioned period. The following localities were sampled during this investigation:

1. Siris village was selected for the main part of this study. For the following reasons: it is the only locality in the district, where only one form of leishmaniasis (VL) has been reported. It is located near four villages that had 42.5% of all reported cases of VL in the district during 1990-1998; and the availability of a house between patients' houses for sandfly collection, which was not sprayed with insecticides before.

Sandflies in this village were collected from, (1) domestic area including fixed site, a house located in the periphery of the village. Light traps were used four times a week for six months; other collection methods were used occasionally. Human landing catches technique was also employed in this house. Furthermore an animal shed for sheep and goat (infested with rodents) located at few meters from human houses, and about 200 m from the first house. (2) Patients' houses in the village by using light traps. (3) Hilly area at 1200 m from the village: Sticky traps were placed, on the trunks of olive, stone fruit and oak trees, and on large stones heaps around these trees. (4) Plain at 600 m from the village, planted with wheat, grains, rain fed vegetables, and

almond and olive trees. Three close fields, one planted with stone fruit trees, the second planted with olive trees, and the third is fallow field and was previously planted with wheat. These fields were selected to set up the sticky traps.

2. Other four neighboring villages (Jaba'a, Jadeida, Maythalun and Sanur). Sandflies were collected from indoor and outdoors of patients' houses those located in peripheral areas, by mainly using CDC light traps.

3. Clusters of localities laid at sides of mountainous area and scope of agricultural plain areas, CL is the main form of leishmaniasis in this area. These included Aba, Al Shuhada, Beit Qad, Bir El Basha, Deir Abu Da'if, Jenin, Qabatiya and Um El Tut. Sandflies were collected from and around patients' houses by using CDC light traps as a main method.

4. Two close localities at a distance of 2 km, namely El Yamun, cases of CL and VL have been reported in the last years, and Silat El Harithiya, where only CL cases have been observed. Sandflies were collected from in and out doors of patients' houses by using CDC light traps.

5. Other six scattered localities, Burqin, El Mughayir, Kufeirat, Rummana, Ya'bad, Zbuba. Sandflies were collected from and around patents' houses by using CDC light traps, and on one occasion, from green house planted with cucumbers and located in Jenin plain at 400 m from Burqin, in addition to CDC light traps sticky traps were also used.

6. Although Tubas and Tayasir were considered from Tubas district, sandflies were collected from these localities around patients' houses, because leishmaniasis cases occurred in these localities recorded in Jenin district.

Description for all sampled localities, number of CL and VL, topography, altitude and rainfall, is given in table (2-1).

Table 2. 1 Characteristics of sampling sites for sandflies in Jenin district during 1998.

Locality	Cases* No. of		Rainfall (mm)	Topography **	Brief description for domestic areas and their surrounding vegetation and animals ***
	CL	VL			
Qabatiya	104	3	550-600	Mountainous area, with many caves, 284-380 m above sea level; soil types Grumusols, and Terra Rossas, and Brown Rendzinas.	All houses are made of concrete with good hygiene standards, surrounded by stone walls, where rats are found. Olive trees are dominant, fruit, almond and other trees (e.g. Quercus sp., and Ceratonta siliqua). Sheep, goat and dogs are present in low density, and only two poultry houses. Irrigated agricultural small plain and green houses at 500 m from houses.
Jenin	90	3	400-500	Mountainous area, with some caves, 134-248 m above sea level; soil type Grumusols.	Cement houses, stone walls are present, Olive and almond trees around houses. Forest of Pinus helepensis are near houses of the cases of CL and VL. Animals in the area including sheep, goat, cows, domestic and stray dogs, rats.
Silat El Harithiya	52	0	400-500	Hilly area, with some caves, 150-195 m above sea level; soil type Grumusols.	Old and new houses are made of cement, with moderate hygiene standard. Olive trees are dominant, and some fruit, and almond trees. Sheep, goat, caws, domestic and stray dogs, rats, and chickens are present in domestic area.
Tubas	36	2	300-400	Mountainous area, 300-400 m above sea level; soil type Grumusols, Terra Rossas, and Brown Rendzinas.	All houses are made of concrete with moderate hygiene standard. Olive fruit and almond trees are present. Sheep, goat, cows, domestic and stray dogs, rats, and chickens are present in domestic area.
El Yamun	32	13	400-500	Mountainous area, with small size caves, 130-251 m above sea level; soil types Grumusols, Terra Rossas, and Brown Rendzinas.	Houses are made of cement with low hygiene standard, stone fences around houses. Olive, fruit, and almond trees are present. Sheep, goat, domestic and stray dogs, rats, and wild animals as foxes (Vulpes cana) are present.
Deir Abu Da'if	27	0	400-450	Mountainous area, with many caves, 180-302 m above sea level, soil Types Grumusols, and Terra Rossas, Brown Rendzinas.	All houses are new made of concrete with moderate hygiene. Olive trees are dominant, fruit and almond, and trees of Qurcus sp. are present. Animals include sheep, goat, domestic and stray dogs, rats, and hyraxes.
Bir El Basha	28	0	450-500	Hilly area, with many caves, 260-336 m above sea level; soil type Brown Rendzinas and Pale Rendzinas.	Old and New houses made of cement, Olive trees are dominant, and some almond trees are present. Sheep, goat, domestic and stray dogs, rats, and wild animals like hyraxes and foxes are found in caves near houses.
Al Shuhada	26	1	450-500	Hilly area, with many caves, 270-366 m above sea level; soil types Grumusols, and Terra Rossas, Brown Rendzinas.	All houses are made of concrete, with low to moderate hygiene standard, irrigated agriculture and greenhouses at 400 m from houses. Olive trees are dominant, and some almond trees are present. Sheep, goat, domestic and stray dogs, rats and hyraxes are animals of the area.
Aba	22	0	450-500	Hilly area, with many caves, 150-200 m above sea level; soil type Grumusols.	Small Village, old and new made of concrete with moderate hygiene. An Olive tree is dominant, fruit, and almond trees. Plain at said of the village planted with wheat and grains. Animals include sheep, goat, domestic and stray dogs, rats, hyraxes, and foxes (Vulpes cana).
Beit Qad	14	0	450-500	Hilly area, with many caves, 190-290 m above sea level; soil type Grumusols.	Small Village, old and new made of concrete with moderate hygiene. An Olive tree is dominant, fruit, and almond trees. Plain at said of the village planted with wheat and grains. Animals include sheep, goat, domestic and stray dogs, rats, hyraxes, and foxes (Vulpes cana).
Tayasir	14	0	300-400	Hilly area, 300-400 m above sea level; soil type Grumusols, Terra Rossas, and Brown Rendzinas.	All houses are made of concrete with low hygiene standard. Olive fruit and almond trees are present. Sheep, goat, caws, dogs, found in most houses, rats, and chickens are present in domestic area.
Sanur	9	1	600-650	Mountainous area, with caves, 375-548 m above sea level; soil Type Grumusols.	All hoses are made of concrete with moderate hygiene. Stone walls around houses, Olive trees are dominant, fruit, and almond trees. Plain at said of the village planted with wheat, grains and some rain fed vegetables and fruit. Sheep, goat, poultry houses, domestic and stray dog, rats, hyraxes, and foxes are present in the area.

Table 2. 1 (continued) Characteristics of sampling sites for sandflies in Jenin district during 1998.

Locality	Cases No. of *		Rainfall (mm)	Topography**	Brief description for domestic areas and their surrounding vegetation and animals***
	CL	VL			
Jadeida	3	15	600-650	Grumusols, and Terra Rossas, Brown Rendzinas. , Mountainous. Altitude 360-539 m above sea level.	All hoses are made of concrete with moderate hygiene. Stone walls around houses, Olive trees are dominant, fruit, and almond trees. Plain at said of the village planted with wheat, grains and some rain fed vegetables and fruit. Sheep, goat, poultry houses, domestic and stray dog, rats, hyraxes, and foxes are present in the area.
Siris	0	5	600-650	Grumusols, and Terra Rossas, Brown Rendzinas. Mountainous area with 375-500 m above sea level.	All hoses are made of concrete with moderate hygiene. Stone walls around houses, Olive trees are dominant, fruit, and almond trees. Plain at said of the village planted with wheat, grains and some rain fed vegetables and fruit. Sheep, goat, poultry houses, domestic and stray dog, rats, hyraxes, and foxes are present in the area.
Meithalun	2	3	600-650	Hilly area with Grumusols soil. And altitude of 350-423 m above sea level.	All hoses are made of concrete with moderate hygiene. Stone walls around houses, Olive trees are dominant, fruit, and almond trees. Plain at said of the village planted with wheat, grains and some rain fed vegetables and fruit. Sheep, goat, poultry houses, domestic and stray dog, rats, hyraxes, and foxes are present in the area.
Jaba	1	2	650-700	Mountainous area with Grumusols, and Terra Rossas, Brown Rendzinas soil. Altitude 350-610 m above sea level.	Most hoses old and new are made of concrete, some houses in the central of the village are made of stone and soil and coated with cement, with low hygiene and crowded, stone walls around houses, Olive trees are dominant, fruit, and almond trees. Plain at said of the village planted with wheat, grains and some rain fed vegetables and fruit. Sheep, goat, poultry houses, domestic and stray dogs, rats, and foxes are present in the area.
Burqin	4	0	450-500	Hilly area, 250-329 m above sea level, Soil type Terra Rossas, Brown Rendzinas.	All houses are made of concrete with moderate hygiene standard surrounded by stone walls. Olive trees are dominant, fruit, and almond. Sheep, goat, dogs, rats and poultry houses are present. Irrigated agricultural and green houses surrounding the village.
Umm Ettut	2	1	400-450	Mountainous area with Grumusols, and Terra Rossas, Brown Rendzinas soil; 275-325 m above sea level.	Small village with new houses made of concrete with poor hygiene, stone walls and crevices in rocks around houses. Olive, almond trees and forest of Pinus helepensis at about 700 m of houses. Sheep, goat, dogs, rats and chicken are present.
El Mughaiyir	3	1	300-350	Mountainous area about 250-375 m above sea level with Terra Rossas, Brown Rendzinas soil.	Houses are made of concrete with moderate hygiene and stone fences around house. Olive trees are dominant, almond trees and forest of Pinus helepensis at about 900 m of houses. Sheep, goat, dogs, rats and are present.
Yabad	2	1	650-700	Mountainous area with 250-350 m above sea level and Pale Rendzinas, and Terra Rossas, Brown Rendzinas soil.	All houses are made of concrete with moderate hygiene standard surrounded by stone walls. Olive trees are dominant, fruit, and almond. Sheep, goat, dogs and rats are present. Many areas around used for coal manufacture.
Kufeirat	1	0	600-650	Mountainous area with 250-350 m above sea level, with Brown Rendzinas and Pale Rendzinas soil.	All houses are made of concrete with moderate hygiene standard surrounded by stone walls. Olive trees are dominant, fruit, and almond. Sheep, goat, dogs and rats are present.
Rummana	1	0	450-500	Hilly area, about 125-200 m above sea level; soil type Brown Rendzinas Pale Rendzinas, Terra Rossas, and Brown Rendzinas.	All houses are made of concrete with moderate hygiene standard surrounded by stone walls. Olive trees are dominant, fruit, and almond. Sheep, goat, dogs and rats are present.
Zububa	2	0	350-400	Hilly area, about 75-125 m above sea level, with Grumusols soil.	All houses are made of concrete with moderate hygiene standard surrounded by stone walls. Olive trees are dominant, fruit, and almond. Sheep, goat, dogs and rats are present.

* Sawalha (unpublished work).
** Applied Research Institute (1996).
*** Data about animals and plants were collected during visits to patients' houses

2.3 Collection Methods

Sandflies were collected using light traps, sticky-paper traps, knock down collection, an aspirator and human-landing collection as described by Lewis (1973), WHO (1984) and Killick-Kendrick (1987).

2.3.1 Light traps

Centers for Disease Control (CDC) miniature light traps (model 512; John W. Hock Co., Gainesville, Florida, USA) with small-mesh collecting bags, and powered by 6 volts rechargeable batteries, was the main collection method used in and outdoors of human houses. Light traps were hanged at a height of 0.5 m above the ground level in collection sites (Lewis, 1973). Traps were placed overnight, one to half an hour before sunset and collected within two hours after sunrise.

2.3.2 Sticky-paper traps

Sticky-paper traps made of ordinary white paper sheets (21X 29 cm), coated on both sides with caster oil and fixed on sticks held vertically at a height of 0.25-0.3 m above the ground level (Lewis, 1973). These traps were fixed overnight. Sandflies and other insects were trapped on the sticky oiled surface when they land. Sandflies were removed from oiled paper using a small fine brush, washed in 10% domestic detergent and processed for identification.

This method was used mainly outdoors and for collection of sandflies in agricultural and natural reserve areas. Traps were sited in and over soil cracks of fallow field, which was previously planted with wheat, on frunks of trees in

almond, olive, and oak trees, on the stone heaps and fences, animal houses and around human dwellings.

2.3.3 Knock down collection

This method was used to collect sandflies resting indoors. Prior to collection, the floor and furniture of a room was covered with white cloth sheets. The door and windows were closed and then the room was sprayed using aerosols of Pyrethrum compounds. The room was left closed for 10-15 minuets, and then opened to pick up knocked-down sandflies using forceps and kept on a humid filter paper and transferred to the laboratory.

It was recognized that this method is better carried out in the early morning, before sandflies exit to rest in cool places. It was not possible in this study to carry out this type of collection before 9 a. m., because of the great nuisance of such process to the dwellings. So that this method were used occasionally according to circumstances.

2.3.4 Human-landing collection

Human-landing collections was used to catch anthropophilic sandflies. Two persons (volunteers) one sat indoors and the other outdoors on a seat and exposed their legs to attract sandflies seeking blood meals. When sandflies bit the volunteers a torch battery light was directed towards the bite site and using an aspirator captured sandflies. Collection was carried out one hour before sunset until one hour after sunrise, other usually residents' activity in the house were taking place during collection. Number of sandfly captured was recorded at one hour interval for all the night. Collected sandflies were kept in a small

plastic jar covered with fine mesh and brought back to the laboratory. The experiment was done in August in Siris Village.

2.3.5 Collecting by aspirator

Trials were carried out to collect sandflies from their suspected resting places, during day time, which include human-dwellings, animal and poultry houses, in cracks and holes in trees and walls, and in places wherever suitable as resting sites for sandflies. Aspirated sandflies were transferred to a small plastic jar covered with fine mesh and send to the laboratory.

2.4 Preparation and Identification of Sandflies

2.4.1 Preparation

Sandflies collected by different methods were brought to the laboratory within two hours of collection. Live sandflies were anesthetized by freezing, washed in 1% water detergent solution for one minute, and then washed by distilled water using fine mesh trap. Dead sandflies that caught by sticky traps coated with castor oil were immersed in 10% detergent solution to remove the oil and for the initial clearing of specimens (Lane *et al.*, 1988). After cleaning, sandflies were preserved in distilled normal saline until they were mounted on the same day. When large numbers were collected, specimens were preserved at 6-8° C until the next day.

2.4.2 Mounting

All preserved sandflies were mounted in Berlese's medium for identification, medium was prepared as described by Lutfy *et al.* (1984). Each

fly was placed in a drop of Berlese medium on a clean slide. Under the dissecting microscope, the head of fly was cut off using a pair of fine needles and placed on its dorsal side near the rest of the body under a coverslip. The last two segments of a female and the wings were also separated from the body and placed under separate coverslips. In case of males the styles were separated apart to clear the genitalia. The preparations were left for some days to permit sufficient clearing of specimens. Microscopic examination was carried out for species identification.

2.5 Isolation of leishmania parasite from sandflies

Sandflies used for this purpose were captured using light traps, aspirator and human landing techniques. Females were separated immediately after cleaning and dissected in sterile saline under a binocular microscope as described by Davis (1967) and Mutinga (1986). The head and dissected guts were examined for leishmania promastigotes using a phase-contrast microscopy. After examination of the head, last two segments and wings were mounted on other slides as described before for species identification.

2.6 Identification of sandfly species

The mounted sandflies were examined under the microscope at 40 X and 100 X.

The main structural features used in species identification were spermatheca of the females, external genitalia of the males, and the pharynx, cibarial tooth structures, mouth parts and wings of both sexes. Identification

were done mainly by using keys of Theodor (1958), Lewis (1967; 1978; 1982), Lane (1986), and Lane *et al.* (1988).

In the female sandflies the shape of spermatheca (smooth, segmented, tubular or globular), their ducts, wall necks and the number of segments, if present, are of high significance in the taxonomy and identification of species. Other taxonomically important characteristics include the following: 1. the terminalia of the males differs in: shape and size of coxite, and the presence or absence of the tuft of hair on it; 2. the style the size and the arrangement of spines and the shape of the aedeagus and paramere; 3. the size and shape of the pharynx and the relative ratio of its width to the anterior part, and the presence or absence of teeth their direction and arrangement in the pharyngeal armature; and 4. the shape of buccal cavity and pigmented plate, the number of teeth of the armature and their direction and shape.

2.7 Meteorological Data

There are three meteorological stations in Jenin district, one in the Jenin City, the second in Meithalun town, and the third near Bait Qad village. The last one was had been out of service for the last 9 years. Meteorological data were obtained from the first two stations and included average relative humidity, wind velocity and temperature at the days of collection. Meithalun station covers the southern area including the following localities in the study: Jaba'a, Jadeida, Meithalun, Sanur and Siris. Jenin station covers the remaining localities under study, however differences in climatic conditions between these localities were negligible.

2.8 Experimental Protocols Used in Sandfly Studies

2.8.1 Distribution of sandflies

Sandflies prevalent in most important leishmaniasis foci in Jenin district, as described in sites of collection section, were surveyed for the whole night and in the morning by using different collecting methods applied in different sandflies' habitats. The whole collections were carried out during the study period, from June to December 1998 were used to determine the general prevalence of different sandfly species in the district.

2.8.2 Human-biting and daily rhythm activity

This part of work was done to determine the species of sandflies biting human and the time of peak activity of biting which represent the most hazardous time to human. It was investigated by using the human-landing collection technique. A single outdoor and another indoor human collectors captured sandflies allowed biting them through the night. This was done 4 times during August and September. Collected sandflies were recorded and processed for identification to determine the anthropophagic sandfly species.

2.8.3 Seasonality of sandflies

The seasonality of nocturnal activity of sandflies were done in Siris village using two CDC light traps, one indoor and one outdoors, 4 times a month, during the period, June-December 1998. Every specimen collected was

identified and numbers of both males and females of different species were recorded. To interpret fluctuations in sandflies populations meteorological data was taken in to consideration.

2.8.4 Engorgement rates

During, collection period all female sandflies were inspected for eggs and freshly blood-feeding status. Comparison was made between different habitats and collection methods.

2.8.5 Sex ratio

All collection sandflies, except those collected by human landing technique (because of it's biased) were used to represent sex ratio, which was expressed as females to males.

2.8.6 Degree of endo- and exophily

Comparisons were made between numbers of sandflies of different sexes and species, collected by CDC light traps at indoor and outdoor of the same house and in the same night, from all sampled localities in the district including the fixed sampling site in Siris village. This was done throughout the study period.

2.8. 7 Attraction to animals

CDC light traps were fixed in an animal house, containing sheep and goats and infested with rats, in Siris village to determine the relative attraction of sandfly species to animals. Trapping was conducted 9 times from September to

November. Those sandflies species were compared with sandflies species collected at same time from the fixed sampling house, located at about 200 m.

2.8.8 Association of sandflies with different plants

Sticky traps were used to investigate effects of plants mainly trees on the distribution of the sandfly species in Siris village. Traps were placed over night on the trunks of trees. Two sandflies collection sites were selected a way from domestic habitat, The first site is a hilly area at 1200 m from human dwellings. Traps were placed three times during September in a field planted with olive (the dominant trees), stone fruit and fig trees, on oak trees in a natural reserve, and traps also fixed on stone heaps around these two habitats. The second site was a plain at 600 m from human dwelling; three close fields were examined, olive, stone fruit and fallow field. This was carried out 6 times during October.

In the second day traps were collected and transported to the laboratory, where they were counted and the number of sandflies / cm ^{2} calculated, species identified and the abundance of different species of sandflies collected in different habitats compared.

CHAPTER THREE

RESULTS

CHAPTER THREE
RESULTS

3.1 Prevalence of Sandfly Species

During the six months of collection, 4082 sandfly specimens were collected from the 23 sampled localities by using different sampling methods. Of the collected sandflies 4073 were identified to species and subspecies level and only 9 were either damaged or lost during preparation. Distribution of sandfly species by collection methods used and by localities is presented in Tables 3.1 & 3.2, and Figure 3.1.

Table 3.1 Species and number of sandflies collected with various collection methods from Jenin district from June to December 1998.

Species	Collection Method					Total
	Light trap	Aspirator	sticky traps	Knockdown	Human landing	
Phlebotomus halepensis	1	-	-	-	-	1
P. jacusieli	4	-	-	-	-	4
P. major	296	3	25	4	16	344
P. mascittii	23	-	5	-	1	29
P. papatasi	254	34	14	51	185	538
P. perfiliewi	675	3	47	2	-	727
P. sergenti	33	-	1	6	-	40
P. (Synphlebotomus) sp.	2	-	2	-	-	4
P. tobbi	315	5	24	5	-	349
Sergentomya christophersi	-	-	1	-	-	1
S. fallax	2	-	-	-	-	2
S. theodori	948	17	1058	-	2	2025
S. tiberiadis	-	-	7	2	-	9
Nonidentified	6	-	1	1	1	9
Total	**2559**	**62**	**1185**	**71**	**205**	**4082**

Table 3. 2 Distribution of sandfly species in Jenin district localities.

locality	Sandfly species												
	Phlebotomus papatasi	*P. perfiliewi*	*P. tobbi*	*P. major*	*P. sergenti*	*P. jacusieli*	*P. halepensis*	*P. mascittii*	*P. (Synphlebotomus) sp.*	*Sergentomya theodori*	*S. fallax*	*S. christophersi*	*S. tiberiadis*
Aba	-	-	-	-	-	-	-	-	-	3	-	-	-
Al Shuhada	2	-	-	1	-	-	-	-	-		-	-	-
Beit Qad	2	102	11	1	4	-	-	-	-	221	-	-	-
Bir El Basha	3	-	1	1	-	-	-	-	-	24	-	-	-
Burqin	1	-	1	2	-	-	-	1	-	38	-	-	-
Deir Abu Daif	7	30	16	5	5	1	1	-	-	167	1	-	-
El Mughayir	-	5	1	-	-	-	-	-	-	24	-	-	-
El Yamun	17	1	6	32	4	1	-	3	-	-	-	-	2
Jaba'a	1	1	3	-	-	-	-	-	-	8	-	-	-
Jadeida	10	17	7	5	1	-	-	-	1	25	-	-	-
Jenin	1	5	8	2	7	-	-	-	-	106	-	-	-
Kufeirat	1	1	1	2	-	-	-	-	-		-	-	-
Maythalun	7	1	-	-	-	-	-	-	-		-	-	-
Qabatiya	17	2	17	21	1	-	-	-	-	24	-	1	-
Rummana	-	7	1	-	1	-	-	-	-	64	1	-	-
Sanur	10	-	2	2	1	-	-	4	-	3	-	-	-
Silat El Harthiya	10	4	3	2	7	-	-	-	-	2	-	-	7
Siris (away from human habitation)	-	44	17	19	-	-	-	-	2	951	-	-	-
Siris (domestic area)	400	484	243	245	1	2	-	19	1	330	-	-	-
Tayasir	8	19	7	2	-	-	-	-	-	13	-	-	-
Tubas	27	3	4	1	6	-	-	1	-	12	-	-	-
Um El Tut	14	-	-	-	-	-	-	-	-		-	-	-
Ya'bad	-	1	-	-	-	-	-	1	-		-	-	-
Zbuba	-	-	-	1	2	-	-	-	-	10	-	-	-
Total	**538**	**727**	**349**	**344**	**40**	**4**	**1**	**29**	**4**	**2025**	**2**	**1**	**9**
(%)	**13.2**	**17.9**	**8.6**	**8.5**	**1.0**	**0.1**	**<0.1**	**0.7**	**<0.1**	**49.7**	**< .1**	**< .1**	**0.2**

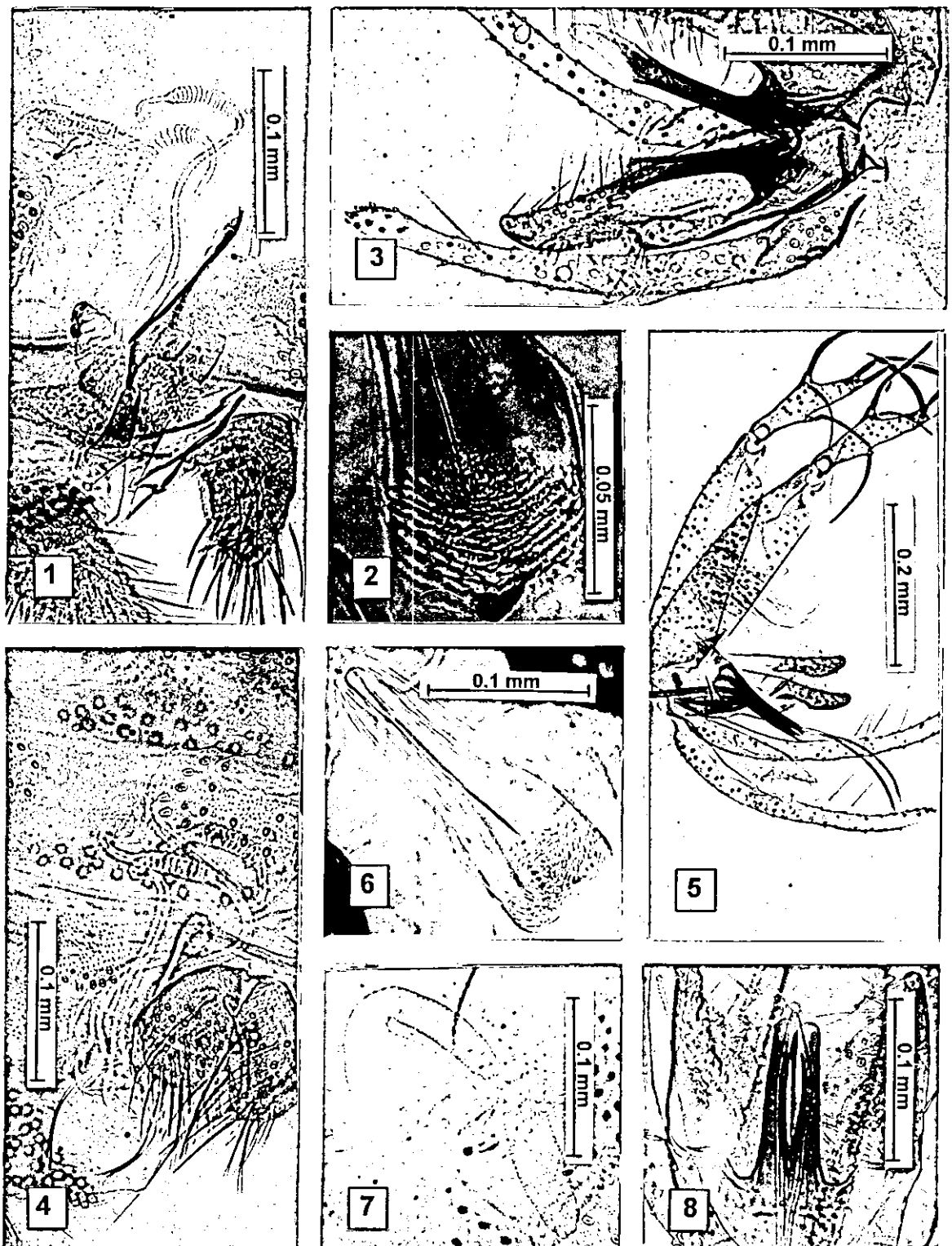
Thirteen species (one of them was only identified to subgenus level) and seven subspecies of sandflies were identified using keys described before. Sandflies species and subspecies collected from the area were:

Phlebotomus (Larroussius) perfiliewi Parrot (Plates 1-3): has three subspecies described by Lewis (1982). Only one of these subspecies, *P. perfiliewi transcaucasicus* was identified from 17 sampled localities, and from sites far from human habitats. It was collected by the different collection methods employed, except human-landing technique. The shape of the base of the spermathecal duct (Plate 1) and pharynx (Plate 2) in females and the shape of aedeagus in males (plate 3) were the main characteristic used to identify this species, and also other species of the *Larroussius* subgenera described below.

P. (Larroussius) tobbi Adler and Theodor (Plates 4 and 5): It occurred throughout the district in most sampled sites including sites far from human habitats. It was collected by all sampling methods used, except human-landing collection method.

P. (Larroussius) mascittii Grassi (plates 6-8), 29 sandflies of this species were collected from six localities, they were caught by sticky, light and human landing traps. The two subspecies, *P. mascittii canaaniticus* Adler and Theodor *and P. mascittii mascittii* Grassi described by Lewis (1984) were found in the area.

P. (Larroussius) major Annandale: collected from 16 localities in the district by all sampling techniques used. Three subspecies (as described by Lewis, (1982) and Killick-Kendrick, personal communication) were identified in the district. These were:



Plates 1-8: 1-3, *Phlebotomus perfiliewi transcucasicus*. (1) ♀, spermathecal ducts; (2) ♀, pharynx; (3) ♂, genitalia. 4, 5, *P. tobbi*. (4) ♀, spermathecal ducts; (5) ♂, genitalia. 6-8, *P. mascittii*. (6) ♀, pharynx; (7) ♀, spermatheca; (8) ♂, aedeagus.

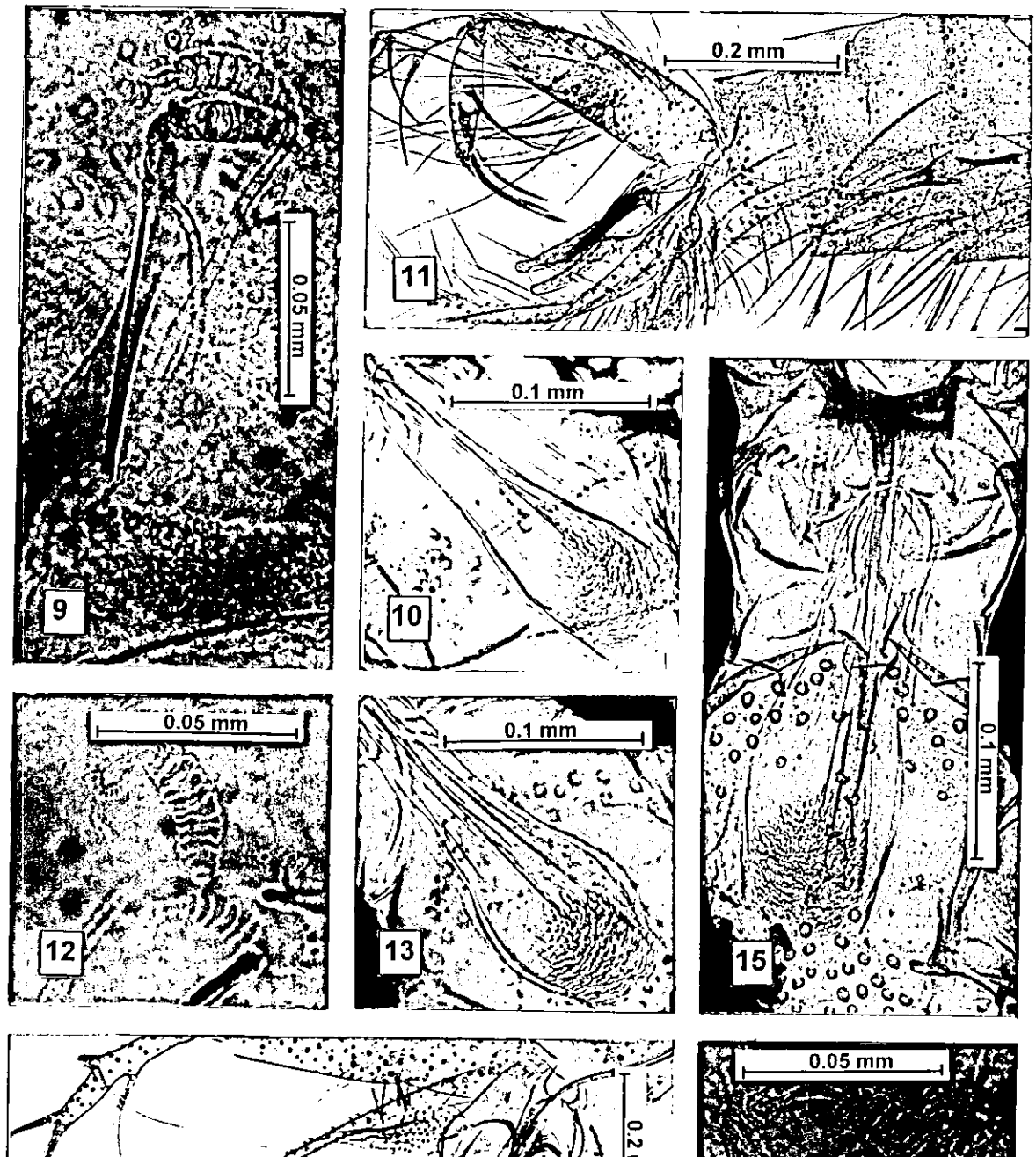
P. major neglectus (plates 9-11): forming 4% of sandflies of this species, *P. major syriacus* (plates 12-14) being the most prevalent of these subspecies in the area consisting 54%, and *P. major major* (plates 15 and 16) represented 43% of the species. Distribution of these subspecies was shown in map 3. 1.

P. (Phlebotomus) papatasi (Scopoli): this species was present in most sampling sites in the district especially in domestic habitats. It was not found away from domestic areas. It was collected by all sampling method used. It is easy to identify this species by the shape of style and its spines (plate 17) in males. In case of females the shape of pharyngeal armature scales, relative length of ascoid on antenna segment number 4 to the length of the segment (Lane, 1986), and spermatheca were used to identify the species (plates 18-20).

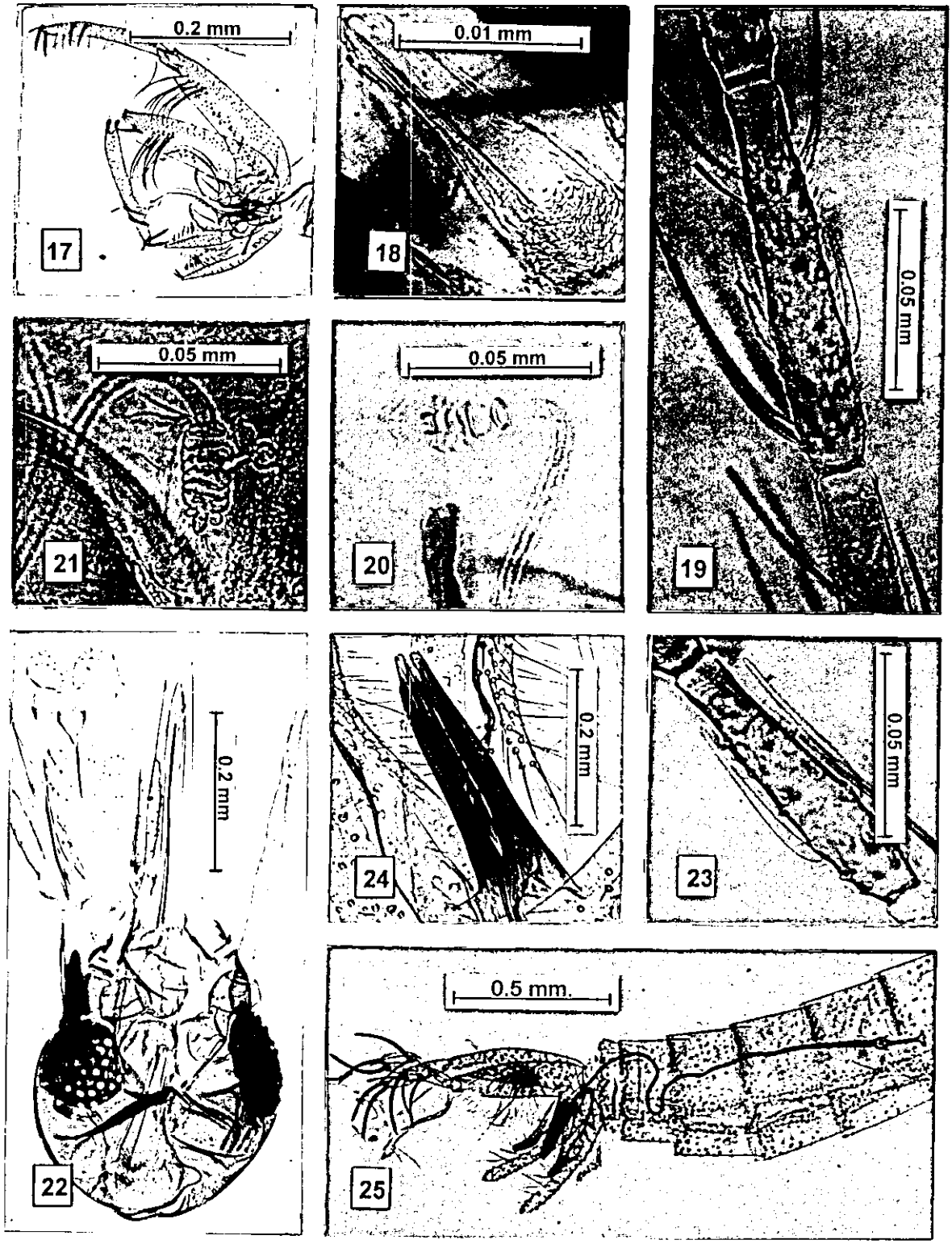
P. (Synphlebotomus) sp. four specimens of the subgenus *Synphlebotomus* Theodor, two females (plates 21-23) and two males (plate 31) were collected both from domestic area and away from human houses in Siris village, and from neighboring village, Jadeida. It was difficult to detect their species by available keys described before, but it is suspected to be *P. rossi* as described by Lewis (1982).

P. (Adlerius) halepensis Theodor: only one male sandfly of this species (plates 24 and 25) was caught by light trap from Deir Abu Daif village.

P. (Paraphlebotomus) sergenti Parrot: this species consisting of two subspecies described by Lewis (1982), 40 sandflies of *P. sergenti sergenti* subspecies (plates 26-28) were identified from 10 localities from human habitat in the study area.



Plates 9-16: 9-11, *Phlebotomus major neglectus*. (9) ♀, spermatheca; (10) ♀, pharynx; (11) ♂, genitalia. 12-14, *P. major syriacus*. (12) ♀, spermatheca; (13) ♀, pharynx; (14) ♂, genitalia. 15, 16, *P. major major*; (15) ♀, pharynx; (16) ♀, spermatheca.



Plates 17-25: 17-20, *Phlebotomus papatasi.* (17) ♂, genitalia; (18) ♀, pharynx; (19) ♀, antennal segment 3; (20) ♀, spermatheca. 21-23, *P. (synphlebotomus)* sp. (21) ♀, spermatheca; (22) ♀, head; (23) ♀, antennal segment 3. 24, 25, *P. halepensis.* (24) ♂, aedeagus; (25) ♂, genitalia and genital filaments.

P. (Paraphlebotomus) jacusieli Theodor: four females of this species (plates 29 and 30) were caught by light traps from three localities.

S. (Sergentomyia) theodori (Parrot): is the most prevalent species in the study area, consisting 49.72% of all catches, it is mainly found away from human habitat. The shape of cibarium teeth and pharynx used for distinguishing both sexes; in addition style shape used to identify males (Plates 32-35).

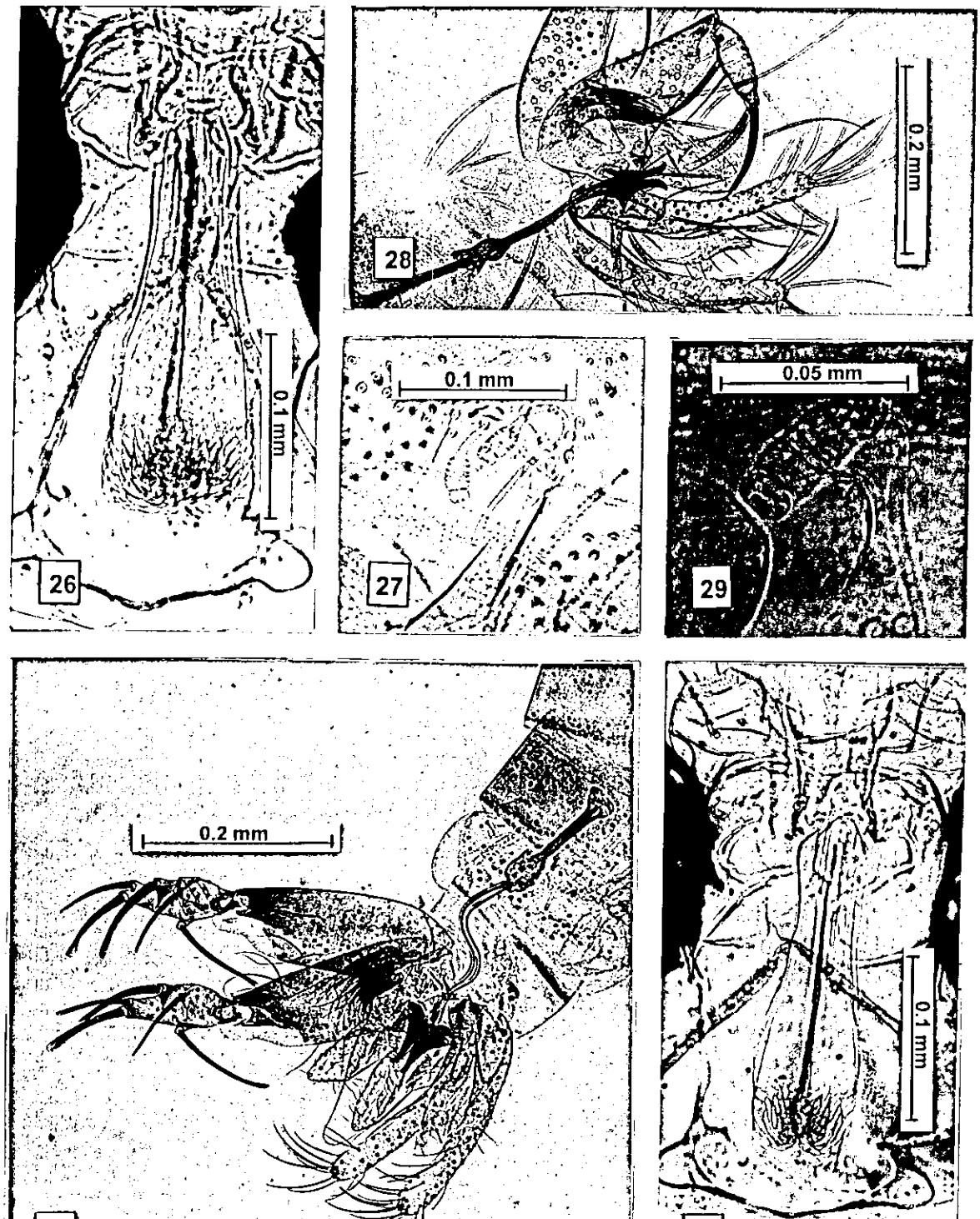
S. (Sergentomyia) fallax (Parrot): two females of this species were caught from different localities by light traps. It is distinguished by using the shape of cibarium and pharynx (plate 36).

S. (Sintonius) christophersi (Sinton): only one specimen (female) of this species was collected around houses in Qabatiya. This species differentiated by the shape of cibarial teeth and pharynx, and spermatheca (plates 37 and 38).

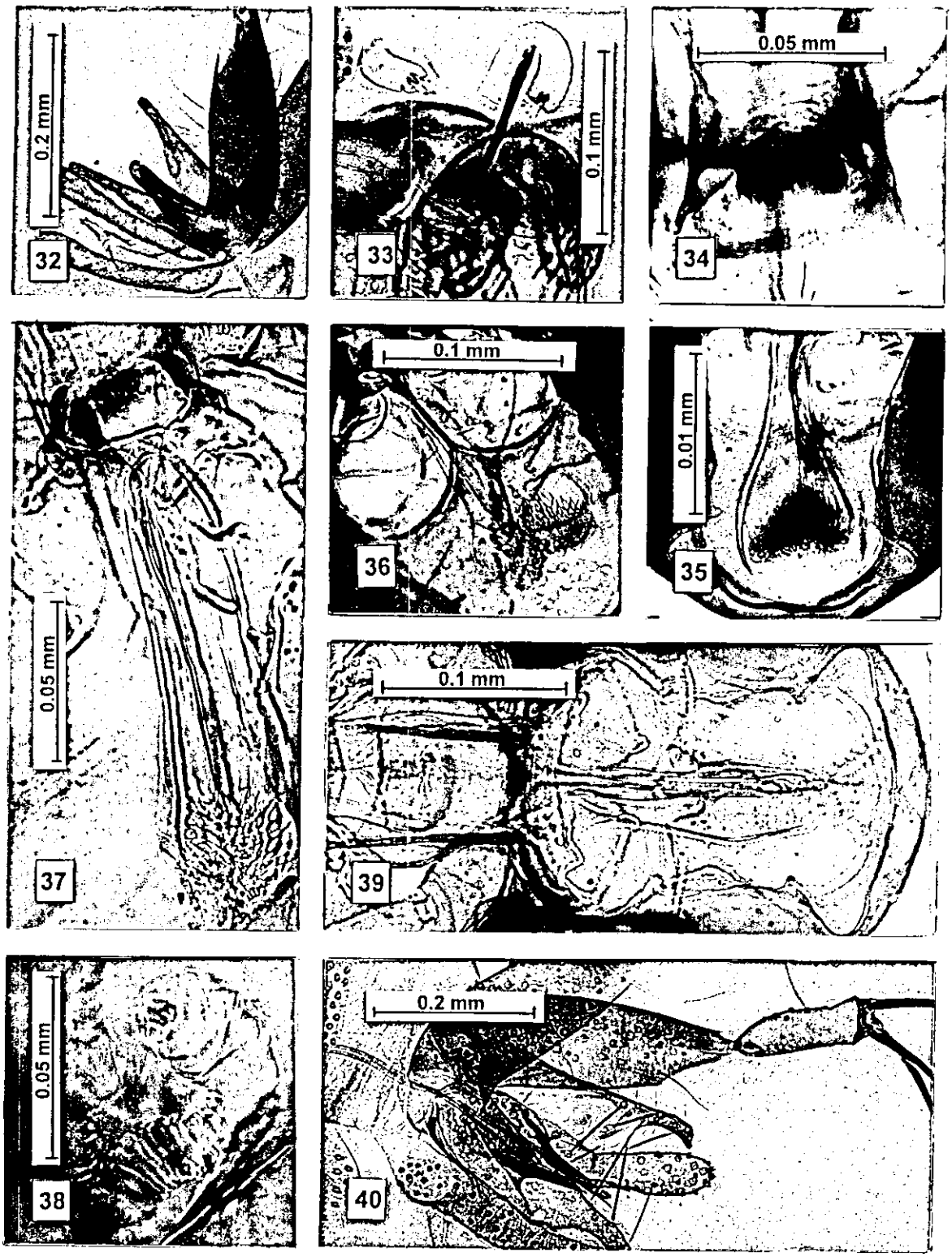
S. (Sintonius) tiberiadis (Adler, Theodore and Lourie): nine flies of this species were collected from two neighboring localities, Silat El Harthiya and El Yamun, in domestic areas. The shape of cibarium and pharynx for females and genitalia for males (Plates 39 and 40) were used to identify the species.

3.2 Parasites Found on Sandfly

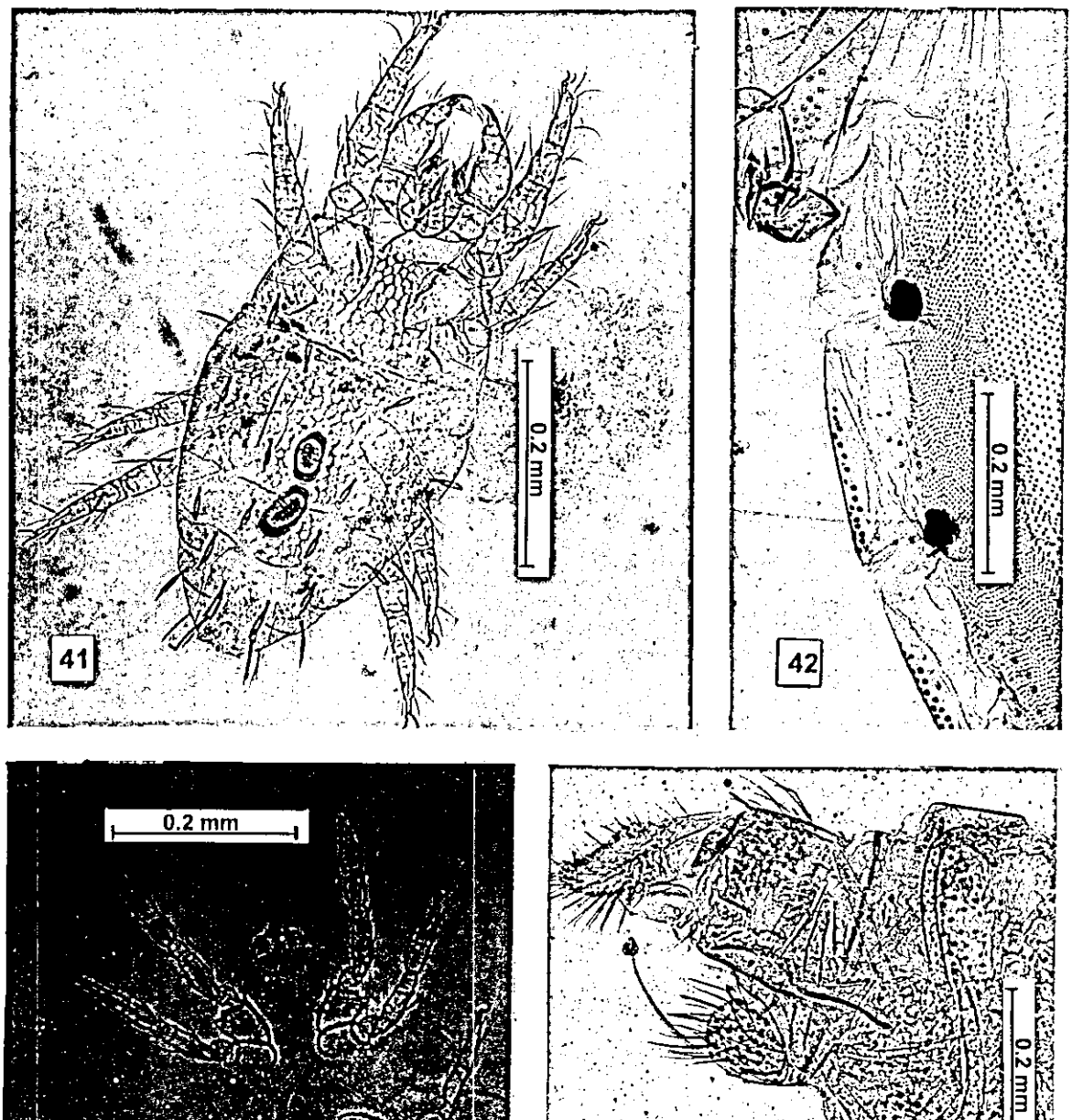
Two different mites were noticed on sandflies during dissecting after they were washed. The first mite (Plate 41) was found on the abdomen of a female *P. papatasi* that was caught by human bait method at an outdoor site in Siris village. Two scars were found on the abdominal segments of this sandfly (Plate 42). The second mite (Plate 43) was isolated from a female *P. sergenti sergenti* collected by CDC light trap fixed outdoors in Silat El Harthiya. And about six nematodes were observed in the last four segments of a female *P. papatasi* caught from Siris by light trap, fixed outdoors (plate 44).



Plates 26-31: 26-28, *Phlebotomus sergenti sergenti.* (26) ♀, pharynx; (27) ♀, spermatheca (28) ♂, genitalia. 29, 30 *P. jacusieli.* (29) ♀, spermatheca; (30), ♀, pharynx. 31 *P. (synphlebotomus)* sp. ♂, genitalia.



Plates 32-40: 32-35, *Sergentomyia theodori.* (32) ♂, genitalia; (33) ♀, spermatheca; (34) ♀, cibarium; (35) ♀, pharynx. 36, *S. fallax*. ♀, pharynx. 37, 38, *S. christophersi* (37) ♀, pharynx and cibarium; (38) ♀, spermatheca. 39, 40, *S. tiberiadis*. (39) ♀, pharynx and cibarium; (40) ♂, genitalia.



Plates 41-44: (41) mite found on the abdomen of ♀ *P. papatasi;* (42) scars present on the abdominal segments of the same sandfly. (43) mite found on the thorax of ♀ *P. sergenti sergenti.* (44), nematodes parasite in abdomen of ♀ *P. papatasi.*

3.3 Distribution of sandflies in different habitats

Table 3. 3 shows the sites in domestic habitats at which different sandfly species were collected. All the thirteen-sandfly species identified in this study also occurred in domestic habitats. Table 3. 4 Shows that only five of these species were caught from different sites (agricultural and wild land areas) far from human habitats (Table 3. 4).

3.3.1 Indoor and outdoor nocturnal activity:

Comparing the indoor and outdoor sandfly species gathered from Jenin district by collection methods applied during night, namely human landing, light and sticky traps (Table 3. 3); it was found that *P. perfiliewi* was the most prevalent species inside houses (31%), followed by *S. theodori* (28 %), *P. papatasi* (21 %), *P. major* (21 %) and *P. tobbi* (10). Two flies of *S. fallax* were caught only indoors. *P. major* comprised *P. m. syriacus* (54 %), *P. m. neglectus* (44 %) and P.m. major (2 %).

The most prevalent outdoor species was *S. theodori* comprising 52 % of all collected sandflies, followed by *P. perfiliewi* (19 %), *P. papatasi* (14 %), *P. tobbi* (7 %), and *P. major* (3.9 %). *P. halepensis* and *P. (Synphlebotomus) sp.* were found in few numbers only outdoors. *P. major* comprised *P. m. syriacus* (59 %), *P. m. neglectus* (37 %) and *P.m. major* (4 %).

The mean of the total number of sandflies per night from different localities was higher outdoors. The percentage of each sandfly species to the total numbers of sandflies collected from the same site, in or outdoor sites, is presented in Tables 3. 3 and Figure 3. 2.

Table 3. 3 Number and percentage of sandflies collected from domestic habitats by various collection methods from Jenin district in 1998.

Species	Site and type of collection method																
	Indoor						outdoor				Animal sheds			Trees around hoses Olive Stone fruit			Stone heaps
	Light trap	Aspirator	sticky trap	Knockdown catches	Human landing	Total	Light trap	Sticky Trap	Human landing	Total	Light trap	Sticky trap	Total	sticky traps	Sticky traps	Total	Sticky trap
Phlebotomus halepensis	-	-	-	-	-	-	1 (0.1)	-	-	1 (0.1)	-	-	-	-	-	-	-
P. jacusieli	1 (0.1)	-	-	-	-	1 (0.1)	3 (0.3)	-	-	3 (0.3)	-	-	-	-	-	-	-
P. major	107 (9.2)	3 (4.8)	-	4 (5.7)	4 (3.5)	118 (8.3)	34 (3.3)	1 (1.4)	12 (13.3)	47 (3.9)	155 (45.1)	2 (33.3)	157 (44.9)	1 (5.9)	-	1 (3.6)	1 (7.7)
P. mascittii	6 (0.5)	-	-	-	-	6 (0.4)	3 (0.3)	4 (5.6)	1 (1.1)	8 (0.7)	14 (4.1)	-	14 (4)	-	-	-	1 (7.7)
P. papatasi	161 (13.8)	34 (54.8)	2 (50)	51 (72.9)	111 (96.5)	359 (25.3)	91 (8.8)	3 (4.2)	74 (82.2)	168 (14.1)	2 (0.6)	1 (16.7)	3 (0.9)	3 (17.6)	-	3 (10.7)	5 (38.5)
P. perfiliewi	404 (34.6)	3 (4.8)	-	2 (2.9)	-	409 (28.8)	224 (21.8)	3 (4.2)	-	227 (19.1)	47 (13.7)	-	47 (13.4)	-	-	-	-
P. sergenti	14 (1.2)	-	-	6 (8.6)	-	20 (1.4)	19 (1.8)	-	-	19 (1.6)	-	-	-	-	-	-	1 (7.7)
P. tobbi	110 (9.4)	5 (8.1)	-	5 (7.1)	-	120 (8.5)	83 (8.1)	3 (4.2)	1 (1.1)	87 (7.3)	122 (35.5)	-	122 (34.9)	1 (5.9)	-	1 (3.6)	2 (15.4)
P. (Synphlebotomus) sp.	-	-	-	-	-	-	2 (0.2)	-	-	2 (0.2)	-	-	-	-	-	-	-
Sergentomya christophersi	-	-	-	-	-	-	-	-	-	-	-	-	-	1 (5.9)	-	1 (3.6)	-
S. fallax	2 (0.2)	-	-	-	-	2 (0.1)	-	-	-	-	-	-	-	-	-	-	-
S. theodori	364 (31.1)	17 (27.4)	2 (50)	-	-	383 (27)	569 (55.3)	50 (70.4)	2 (2.2)	621 (52.2)	4 (1.2)	3 (50)	7 (2)	11 (64.7)	11 (100)	22 (78.6)	3 (23.1)
S. tiberiadis	-	-	-	2 (2.9)	-	2 (0.1)	-	7 (9.9)	-	7 (0.6)	-	-	-	-	-	-	-
Total	1169 (100)	62 (100)	4 (100)	70 (100)	115 (100)	1420 (100)	1029 (100)	71 (100)	90 (100)	1190 (100)	344 (100)	6 (100)	350 (100)	17 (100)	11 (100)	28 (100)	13 (100)

Table 3. 4 Number and percentage of sandflies gathered from different agricultural and wild land habitats by various collection methods from Jenin district, 1998.

Species	Site collection and type of the trap						Total
	Green house	Olive trees	Almond trees	Oak trees	Fallow field	Stone heaps	
	Light trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	
P. major	-	4 (1.4)	5 (0.9)	-	3 (8.3)	8 (4.7)	20 (1.9)
P. perfiliewi	-	1 (0.3)	5 (0.9)	-	31 (86.1)	7 (4.1)	44 (4.1)
P. (Synphlebotomus) sp.	-	-	-	-	-	2 (1.2)	2 (0.2)
P. tobbi	-	2 (0.7)	5 (0.9)	-	2 (5.6)	9 (5.3)	18 (1.7)
S. theodori	11 (100)	281 (97.6)	543 (97.3)	9 (100)	–	145 (84.8)	989 (92.1)
Total	11 (100)	288 (100)	558 (100)	9 (100)	3 6 (100)	171 (100)	1073 (100)

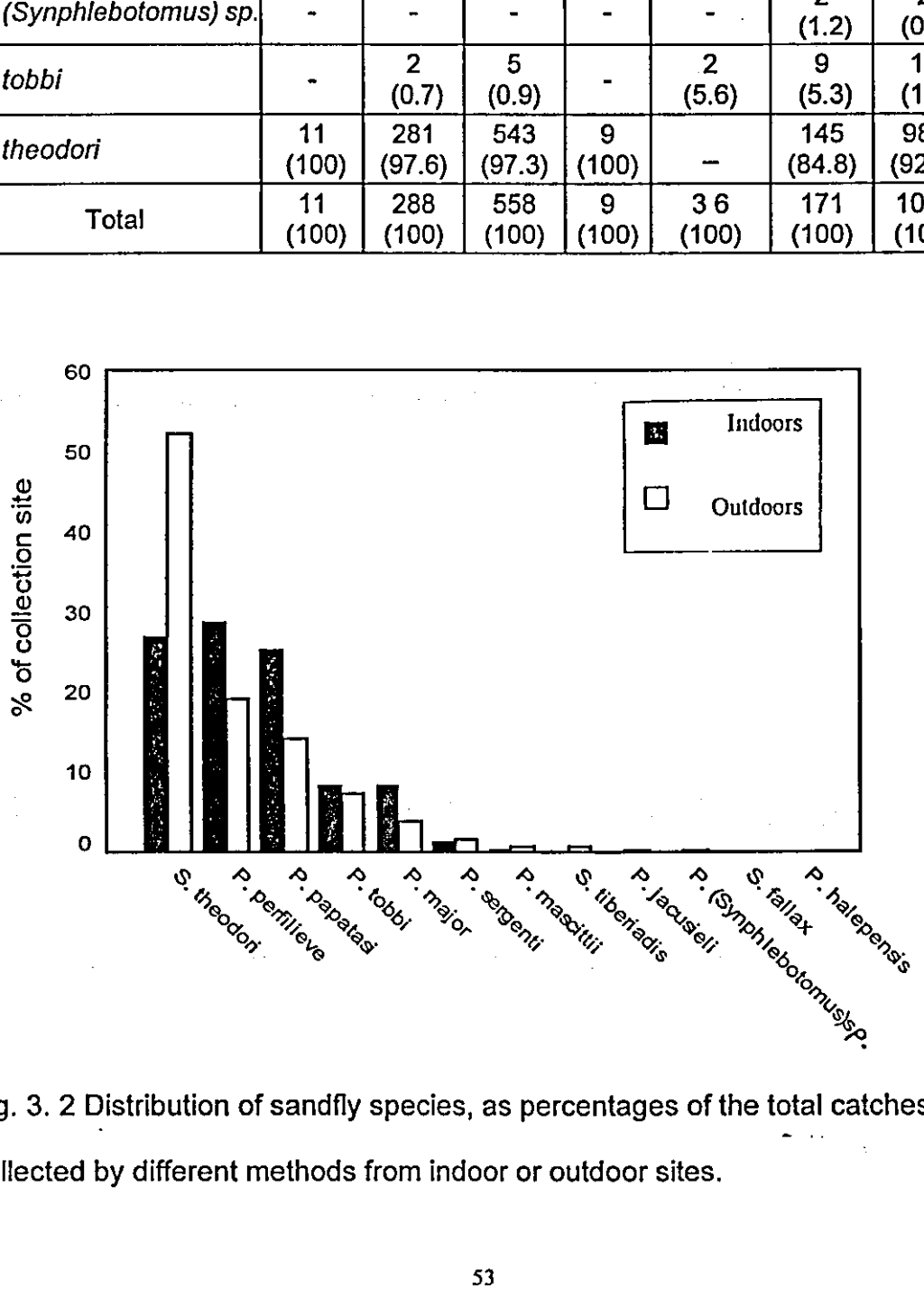


Fig. 3. 2 Distribution of sandfly species, as percentages of the total catches collected by different methods from indoor or outdoor sites.

3.3.2 Diurnal resting sites:

The aspiration method failed to collect sandflies from outdoor sites such as trunks of trees, animal sheds, stone heaps and cracks.

The only resting site during daytime between 10: 00 a. m. and 12: 00 noon was observed indoor. *P. papatasi* found to be the most abundant species comprising about 73 % and 55 % of sandflies caught by knock down and aspiration techniques, respectively. Other species found were *P. perfiliewi*, *P. tobbi, P. major, P. mascitti, P. sergenti* and *P. theodori.*

The most preferred resting site for sandflies was top corners just bellow ceiling in bedrooms and sometimes in bathrooms.

3.3.3 Distribution of sandflies on different vegetation:

The most abundant species of sandflies collected from different fields planted with various types of trees in domestic and agricultural and wild lands was *S. theodori* (Table 3. 3 & 3. 4); it was on the other hand, completely absent from fallow field. Other species found were less abundant and included *P. major, P. tobbi* and *P. perfiliewi. Phlebotomus papatasi* was only caught from fields of olive trees in domestic habitats.

Only nine flies of *S. theodori* were caught from oak trees forest near Siris village during 10 trap-night during August. No sandflies were caught from a pine forest near Jenin city during 6 trap-night.

The mean density of different sandfly species (Number of sandflies / m^2 / night) on different vegetation is presented in Table 3. 5. *S. theodori* had the highest mean density in almond orchard followed by olive orchard; but no flies

of this species were caught from fallow field at 50 m away from these fields. On the other hand, *P. perfiliewi* was found to be the most prevalent species in fallow fields.

Table 3. 5 Mean density (Number / m² / night) of different sandfly species collected from three closed fields in Siris using sticky traps in nine trap night in October 1998.

Species	Olive orchard	Almond orchard	Fallow field
p. major	0.6	1.7	2.0
P. perfiliewi	0.2	1.5	23.3
p. tobbi	0.4	1.7	1.3
S. theodori	51.5	85.0	0.0
Mean of totals	**52.7**	**89.9**	**26.6**

3.3.4 Attraction of sandflies to animal sheds:

Collection of sandflies from sheep and goat sheds in Siris village was carried out for nine trap night during October and November. Six species of sandflies were collected from animal houses, *P. major, P. tobbi* and *P. perfiliewi* were the most prevalent ones, comprising about 45 %, 36 % and 13 % respectively, of all sandflies collected mainly by light traps (Tables 3. 3). Other species occurred at very low numbers (Table 3. 3). *P. major* comprised *P. m. syriacus* (60 %), *P. m. neglectus* (36 %) and *P.m. major* (4%).

Table 3. 6 Compares densities of different species of sandfly collected in nine trap night from animal sheds in and outdoors from Siris using light traps during October to November. Mean densities of the above- mentioned six species

were higher in animal sheds except for *S. theodori*, which was collected from both indoor and outdoor sites, and *P. papatasi*, which was caught only indoors.

Table 3.6 Mean density (Number / trap night) of sandflies caught by light traps in animal sheds, outdoor and indoor in Siris village during October and November 1998.

Species	Animal sheds M ± S. D.	Indoor M ± S. D.	Outdoor M ± S. D.
p. major	17.2 + 13.8	2.8 + 2.4	0.2 +0.4
P. mascitti	1.5 + 2.1	0.0 + 0.0	0.0 + 0.0
P. papatasi	0.2 + 0.7	1.7 + 1.8	0.0 + 0.0
P. perfiliewi	5.2 + 8.1	10.8 + 16.2	1.4 + 2.4
p. tobbi	13.6 + 16.4	3.3 + 3.4	0.4 + 0.7
S. theodori	0.4 + 0.7	3.3 + 5.0	0.9 + 1.4
Mean	**38.2 + 32.6**	**22 + 25.9**	**3.0 + 3.9**

3.3.5 Attraction of sandflies to stone heaps

Sandfly species collected from stone heaps in domestic habitats by sticky traps included *P. papatasi* (38.5 %), *S. theodori* (23 %), *P. tobbi* (15 %), *P. major*, *P. mascitti* and *P. sergenti* (about 8 % each) (Table 3. 3). In the agricultural and wild land habitats, species caught from stone heaps included *S. theodori* (85 %), *P. major* (5 %), *P. tobbi* (5 %), *P. perfiliewi* (4 %) and *P. (Synphlebotomus) sp.* (1 %) (Table 3.4).

3.4 Sex ratio

The total number of females caught during this study was comparable to that of males (2703: 1371, sex ratio = 2 : 1). In general more females were collected than males in different habitats by various collection methods (Table 3. 7). Except the following: 1. *P. papatasi* collected from indoor by light traps; 2. *P.*

major and *P. tobbi* collected from inside houses by aspiration method; 3. *P. papatasi* and *S. tiberiadis* caught by sticky traps at outdoors; and 4. *S. theodori* collected by sticky traps fixed around stone heaps and olive trees in agricultural and wild lands. In the fallow fields only males were caught, and one sex was collected in many other occasions.

3.5 Engorgement and Gravid rates

Table 3. 8 Shows freshly blood fed or gravid females caught from domestic habitats, mainly by light traps, and from agricultural lands, mainly by sticky traps. More than 50% of *P. papatasi* caught from domestic areas were freshly blood fed or gravid. Neither freshly blood fed nor gravid females of this species found in animal sheds or other habitats.

More gravid or freshly fed females (30 %) of *Phlebotomus* species were collected from indoor than from outdoor. In animal sheds, about 28 % of *P. major* females were found freshly fed, and no gravid female of any species was caught.

In general the percentage of gravid or freshly fed females of *Sergentomyia* species was very low in different habitats, and the same is true for all collected species from agricultural and wild land habitats.

Table 3. 7 Sex ratio (female: male) for sandfly species collected by various methods from different habitats in Jenin district.

Species	Site and type of collection method																	
	Domestic habitat											Agricultural and wild lands habitat					
	Indoor				Outdoor		Animal houses		Olive trees	Almond trees	Stone heaps	Olive trees	Almond trees	Stone heaps	Oak trees	Green House	Fallow field
	Light trap	Aspirator	Sticky trap	Knock down	Light trap	Sticky trap	Light trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Sticky trap	Light trap	Sticky trap
	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂	♀ : ♂
Phlebotomus halepensis	-	-	-	-	1♂	-	-	-	-	-	-	-	-	-	-	-	-
P. jacusieli	1♀	-	-	-	3♀	-	-	-	-	-	-	-	-	-	-	-	-
P. major	3:1	0.5:1	-	1:1	0.79	1♂	2.4:1	2 ♂	1 ♂	-	1 ♂	0.3:1	0.3:1	8 ♂	-	-	3 ♂
P. mascittii	6 ♀	-	-	-	0.5	1:1	13:1	-	-	-	1 ♂	-	-	-	-	-	-
P. papatasi	0.8:1	1.1:1	1:1	0.8:1	2.4:1	0.5:1	2♀	1♂	3 ♂	-	4:1	-	-	-	-	-	-
P. perfiliewi	1.7:1	3 ♀	-	1:1	0.44	2:1	14.6:1	-	-	-	-	1 ♀	1.5:1	0.2:1	-	-	31 ♂
P. sergenti	1.8:1	-	-	1:1	0.27	-	-	-	-	-	1 ♂	-	-	-	-	-	-
P. Synphlebotomus) sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	1:1	-	-	-
P. tobbi	2.5:1	0.7:1	-	0.7:1	0.63	2:1	9.1:1	-	1 ♂	-	2 ♂	1:1	0.3:1	9 ♂	-	-	2 ♂
S ergentomya christophersi	-	-	-	-	-	-	-	-	1 ♀	-	-	-	-	-	-	-	-
S. fallax	2♀	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. theodori	3:1	4.7:1	1:1	-	0.20	5:1	4 ♀	3 ♀	10:1	1.8:1	2:1	0.8:1	0.9:1	5.3:1	0.29	1.2:1	-
S. tiberiadis	-	-	-	1:1	-	0.7:1	-	-	-	-	-	-	-	-	-	-	-
Total	2:1	1.6:1	1:1	0.9:1	0.34	2.7:1	4.5:1	1:1	1.8:1	1.8:1	0.9:1	0.8:1	0.9:1	2.6:1	0.29	1.2:1	36 ♂

Table 3. 8 Percentage of fresh-fed* and gravid sandfly females from total females collected from different habitats in Jenin district.

Species	Indoor*			Outdoor*			Animal sheds			Olive trees**			Almond trees**			Stone heaps**		
	Freshly fed (%)	Gravid (%)	Total No. of females	Freshly fed (%)	Gravid (%)	Total No. of females	Freshly fed (%)	Gravid (%)	Total No. of females	Freshly Fed (%)	Gravid (%)	Total No. of females	Freshly fed (%)	Gravid (%)	Total No. of females	Freshly fed (%)	Gravid (%)	Total No. of females
Phlebotomus jacusieli	-	-	1	-	33.3	3	-	-	-	-	-	-	-	-	-	-	-	-
P. major	19.8	13.6	81	-	26.7	15	27.8	-	108	-	-	1	-	-	1	-	-	-
P. mascittii	66.7	-	6	-	50.0	2	15.4	-	13	-	-	-	-	-	-	-	-	-
P. papatasi	29.5	34.1	88	34.2	23.6	38	-	-	-	-	-	-	-	-	-	-	-	-
P. perfiliewi	17.9	8.6	257	15.5	9.6	142	4.7	-	43	-	100	1	-	33.3	3	-	-	1
P. sergenti	22.2	11.1	9	0.7	46.7	15	-	-	-	-	-	-	-	-	-	-	-	-
P. (Synphlebotomus) sp.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
P. tobbi	13.9	12.7	79	8	8	50	6.4	-	110	-	-	1	-	-	1	-	-	-
Sergentomya fallax	-	50.0	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. theodori	2.4	11.7	282	0.2	5.2	516	-	-	6	-	1.6	121	-	-	254	0.8	1.6	122
S. tiberiadis	-	100	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
% of total females	12.5	13.5	806	5.2	8.4	785	14.6	-	280	-	2.4	124	-	0.4	259	0.8	1.6	124

* Excluding sandflies collected from human landing method.

* * Collected from agricultural and wild lands only mainly by sticky traps.

3.6 Monthly fluctuations of sandfly species

Daily fluctuations in the means of temperature, relative humidity and wind velocity at the time of sandfly collection are presented in Figure 3. 3 (A).

Monthly fluctuation in the mean number of most abundant sandfly species collected during June to December 1998 from a house at each of two sites indoor and outdoor in Siris village are presented in Figure 3. 3 B-F.

Indoor collections, showed that *P. perfiliewi* had the highest density compared with other sandfly species. It peaked during August, whereas *P. papatasi* peaked in July and August. The highest abundance of other species *P. major, P. tobbi and S. theodori* were recorded during September, October and July respectively. The density of all species dropped markedly in November.

Outdoor collections showed that *P. major, P. papatasi, P. tobbi* and *S. theodori* peaked in July, and in July and August for *P. perfiliewi.* Also these species dropped markedly during November except in *P. major* which showed dramatic decrease in August.

All other species identified in this study were rare throughout the study period. No sandflies were found in the area after November, with the start of winter, the rainy season.

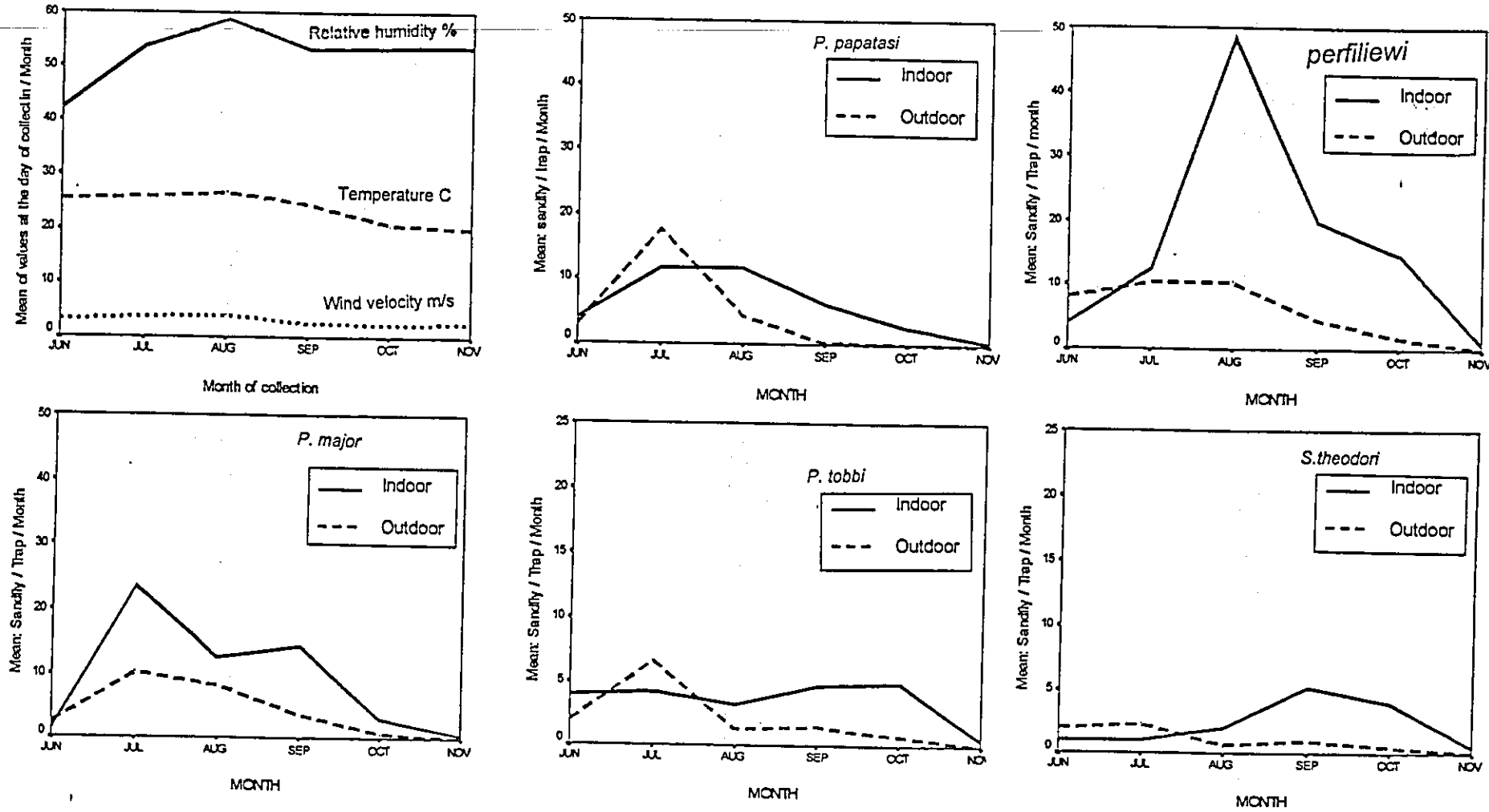


Fig. 3. 3 (A-F): (A) Mean monthly of temperature, relative humidity and wind velocity at the days of collection. (B-F) Mean monthly number of the main sandfly species caught by CDC light traps placed indoor (solid lines) and outdoor (cut lines) at a house in Siris village from June to December 1998

The relationship between mean of temperature, relative humidity and wind velocity and mean number of different sandfly species collected by light traps from indoor and outdoor of a house in Siris village during June to November is presented in Tables 3. 9 & 3. 10. Correlation was observed between both mean of temperature as well as wind velocity and numbers of *P. major* and between wind velocity and density of *P. tobbi* for sandflies collected from indoor. Correlation was only found between wind velocity and number of *S. theodori* for sandflies caught from outdoor.

3.7 Effect of altitude on Sandfly

Because sandfly collections from various altitudes was not repeated equal times and not done at the same time and conditions, the percentage of each species from the total number of sandflies collected by light trap from the same altitude was considered in order to study the effect of elevation on the distribution of sandfly species.

S. theodori was found to be the most prevalent species at different altitudes especially at an altitude less than 300 m(Table 3. 11). *P. papatasi, P. major* and *P. tobbi* constituted the highest percentages of sandflies collected at elevations between 200 to 300 m. On the other hand *P. perfiliewi* constituted the highest percentage at higher elevations between 400 and 500 m.

Table 3. 9 Correlation between number of sandflies collected from indoor, and climatic conditions.

Climate variable	Sandfly species	Correlation Factor (r)	P value
Mean of Daly temperature	*p. major*	-0.39*	0.01*
	P. papatasi	-0.01	0.93
	P. perfiliewi	-0.09	0.55
	P. sergenti	0.24	0.12
	P. tobbi	-0.28	0.07
	S. theodori	0.21	0.18
Average of relative humidity	*p. major*	0.11	0.49
	P. papatasi	-0.28	0.07
	P. perfiliewi	0.05	0.76
	P. sergenti	0.15	0.35
	P. tobbi	-0.16	0.31
	S. theodori	0.05	0.76
Average of wind velocity	*p. major*	-0.34*	0.03*
	P. papatasi	-0.13	0.41
	P. perfiliewi	-0.13	0.41
	P. sergenti	0.18	0.26
	P. tobbi	-0.35*	0.02*
	S. theodori	0.14	0.38

* Correlation is significant at the 0.05 level.

Table 3. 10 Correlation between number of sandflies collected from outdoor and climatic condition.

Climate variable	Sandfly species	Correlation factor (r)	P value
Mean of Daly temperature	*p. major*	-0.10	0.51
	P. papatasi	0.04	0.79
	P. perfiliewi	0.20	0.20
	P. sergenti	0.22	0.15
	P. tobbi	0.19	0.23
	S. theodori	0.29	0.06
Average of relative humidity	*p. major*	-0.05	0.74
	P. papatasi	-0.08	0.61
	P. perfiliewi	0.11	0.47
	P. sergenti	0.19	0.22
	P. tobbi	0.06	0.72
	S. theodori	0.22	0.16
Average of wind velocity	*p. major*	-0.17	0.29
	P. papatasi	-0.08	0.61
	P. perfiliewi	0.19	0.22
	P. sergenti	0.19	0.22
	P. tobbi	0.06	0.71
	S. theodori	0.35*	0.02*

* Correlation is significant constituted at the 0.05 level.

Table 3. 11 Distribution of sandflies according to altitude at the different localities surveyed at the Jenin district, 1998.

Species	Altitude (m)				Total (%)
	100-199 (%)	200-299 (%)	300-399 (%)	400-499 (%)	
P. papatasi	28 (4.5)	30 (7.7)	87 (14.3)	1 (2.1)	146 (8.7)
P. perfiliewi	117 (18.6)	42 (10.8)	82 (13.5)	13 (27.1)	254 (15.2)
P. major	38 (6)	45 (11.5)	155 (25.5)	6 (12.5)	244 (14.6)
P. tobbi	28 (4.5)	62 (15.9)	132 (21.7)	3 (6.3)	225 (13.4)
P. sergenti	24 (3.8)	6 (1.5)	8 (1.3)	1 (2.1)	39 (2.3)
P. mascittii	3 (0.5)	6 (1.5)	17 (2.8)	-	26 (1.6)
P. jacusieli	1 (0.2)	1 (0.3)	-	-	2 (0.1)
P. halepensis	-	1 (0.3)	-	-	1 (0.1)
P. (Synphlebotomus) sp.	-	-	-	1 (2.1)	1 (0.1)
S. theodori	380 (60.4)	196 (50.3)	125 (20.6)	23 (47.9)	724 (43.2)
S. tiberiadis	9 (1.4)	-	-	-	9 (0.5)
S. fallax	1 (0.2)	1 (0.3)	-	-	2 (0.1)
S. christophersi	-	-	1 (0.2)	-	1 (0.1)
Total	629 (100)	390 (100)	607 (100)	48 (100)	1674 (100)

3.8 The Human-biting sandflies

The number of human-biting sandfly species collected from Siris village in four nights (during August and September) are shown in Table 3. 12. The human biting sandfly species found indoor in the area were *P. papatasi* and *P. major* (*P. m. neglectus* and *P. m. syriacus*). In addition to these two species two other human biting species were found outdoor in few numbers (*P. mascittii* and *S. theodori*).

Phlebotomus papatasi was found to be the main human biting species indoor and outdoor constituting 96.5% and 82.2%, respectively.

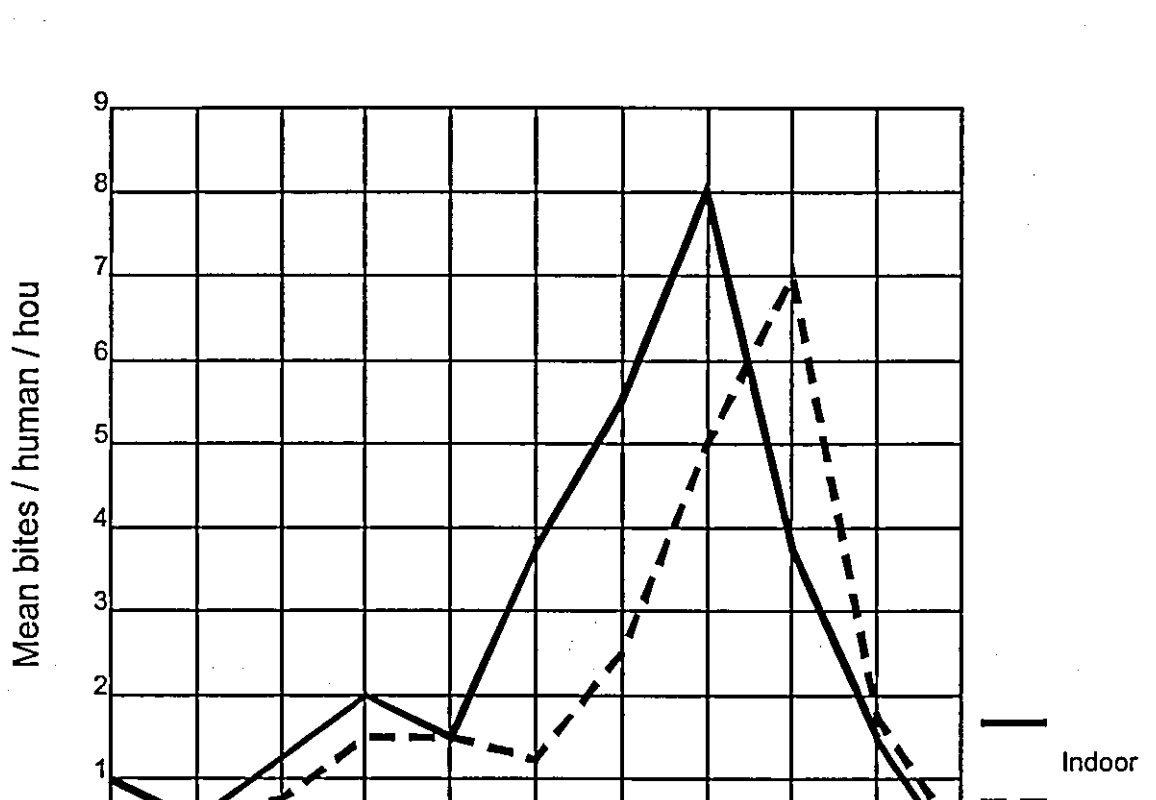
The means of human biting rate (bites / man / night) of sandflies were 28.75 and 22.5 indoor and outdoor, respectively.

The mean number of human-biting sandflies was higher inside houses than outside, from 20:00 p.m. to 03:30 a.m. mean number of human biting sandflies were higher outdoor than indoor. The highest mean number of human-biting female sandflies was collected indoor and outdoor between 02- 03 and 03-04 a.m., respectively (fig. 3. 4).

Table 3. 12 Sandfly collected by human landing technique from indoor and outdoors, at Siris village, 1998.

Species	Trap location		Total
	Indoor	outdoor	
P. major	4	12	16
P. mascittii	0	1	1
P. papatasi	111	74	185
P. tobbi	0	1	1
S. theodori	0	2	2
Total	115	90	205

Figure 3.4 Human-biting catches of sandfly (based on means of four collection nights from indoor and outdoor) at fixed location in Siris village for August and September 1998.



3.9 Distribution of sandfly species in leishmaniasis foci

Studied localities were classified into three categories according to type(s) of leishmaniasis reported in each one; these categories were localities of CL, localities of VL, and localities of CL and VL. Because *Sergentomyia* species are not considered as vectors of leishmaniasis, they were ignored. Table 3. 13 Shows sandflies species collected from indoor and outdoor at these three disease foci.

P. perfiliewi was found to be the most prevalent species(a total of 628 flies, constituting 49.7%) in the three types of infected areas; other abundant species in areas infected with CL were *P. tobbi* (19.7%), *P. papatasi* (13.1%), *P. sergenti* (11.7%) and *P. major* (8%). In localities infected with VL, the abundant species were *P. papatasi* (22.7%), *P. tobbi* (14.5%) and *P. major* (8.6%); and the abundant species, where the two type of leishmaniasis reported, were *P. major* (19.5%), *P. papatasi* (15.5%)and *P. tobbi* (15.5%). Table 3. 14 Shows sandfly species collected from inside houses of patients of CL and VL and houses without leishmaniases cases in infected localities in Jenin district.

The most prevalent sandfly species found inside houses of CL patients was *P. papatasi* (33.8 %) followed by *P. perfiliewi* (29.2%), *P. tobbi* (16.9%), *P. major* (13.8%), and *P. sergenti* (6.2 %). In houses of VL patients *P. major* (38.8 %) was the most prevalent species followed by *P. papatasi* (31.8 %), *P. tobbi* (15.3 %), *P. perfiliewi* (4.7 %) and *P. sergenti* (4.7 %). In other houses where no cases of leishmaniasis have been reported, *P. papatasi* (34.7 %) and *P. perfiliewi* (34.7 %) was the most prevalent species.

Table 3. 13 Distribution of sandfly species collected from human habitats, in and outdoors, at Jenin district according to type of leishmaniasis in each one.

Species	Disease in the area			Total (%)
	CL (%)	VL (%)	CL & VL (%)	
P. halepensis	1(0.1)	0 (0.0)	0 (0.0)	1(0.1)
P. jacusieli	1(0.1)	2(0.2)	1(0.3)	4(0.3)
P. major	11(8.0)	71(8.6)	59(19.5)	141(11.2)
P. mascittii	1(0.1)	3(0.4)	5(1.7)	9(0.7)
P. papatasi	18(13.1)	187(22.7)	47(15.5)	252(20.0)
P. perfiliewi	62(45.3)	436(52.9)	130 (42.9)	628(49.7)
P. sergenti	16(11.7)	4(0.5)	13(4.3)	33(2.6)
P. (Synphlebotomus) sp.	(0.0)	1(0.1)	1(0.3)	2(0.2)
P. tobbi	27(19.7)	119(14.5)	47(15.5)	193(15.3)
Total	137(100)	823(100)	303(100)	1263(100)

Table 3. 14 Distribution of sandfly species and subspecies collected by different collecting methods from inside houses of leishmaniasis patients and their vicinity in Jenin district.

Species	Type of leishmaniasis in the house where sandflies were collected			Total (%)
	CL (%)	VL (%)	No cases * (%)	
P. jacusieli	0 (0.0)	1 (1.2)	0 (0.0)	1 (0.2)
*P. major***	27(13.8)	33 (38.8)	10 (13.3)	70 (19.7)
P. mascittii	0 (0.0)	3 (3.6)	3 (3.9)	6 (1.1)
P. papatasi	66 (33.8)	27 (31.8)	26 (34.7)	119 (21.3)
P. perfiliewi	57 (29.2)	4 (4.7)	26 (34.7)	87 (15.6)
P. sergenti	12 (6.2)	4 (4.7)	3 (4.0)	19 (3.4)
P. tobbi	33 (16.9)	13 (15.3)	7 (9.3)	53 (9.5)
Total	195 (100)	85 (100)	75 (100)	355 (100)

* Excluding fixed location in Siris village.

** This species consisting of three subspecies. At houses of CL patients, *P. m. syriacus* =16 and *P. m. neglectus* = 11; at houses of VL patients, *P. m. syriacus* =11 and *P. m. neglectus* = 22 and at houses with no cases of leishmaniasis, *P. m. syriacus* =8, *P. m. neglectus* = 1 and *P. m. major* = 1.

3.10 Isolation of leishmania parasite

No leishmania parasite was found following the dissection and examination of 923 females of sandflies. Dissected females included *P. perfiliewi* (410), *P. tobbi* (225), *P major* (175), *P. papatasi* (90), *P. sergenti* (18), *P. mascittii* (15) and *P. jacusieli* (2).

3.11 Efficiency of trapping methods

Tables 3.1, 3.3 and 3.4 show the efficiency of various techniques used in collecting sandfly species in Jenin district. Use of certain trapping methods was determined by the circumstances of examined habitat. For instance sticky traps were not preferred for use indoor or in animal sheds because of residents objection. Light traps was also not used in the agricultural and wild lands to prevent their loss or damage.

A total of 2559 sandflies, including 11 species, were collected from different localities by CDC light traps in 108 trap night. The light traps collected the highest number of sandflies per night from animals sheds followed by traps in outdoor and indoor. The maximum number of sandflies collection was 264 sandflies from a trap placed outdoors in Bit Qad village (Table 3. 15).

Table 3. 15 The mean number of sandflies collected by light trap per night from different habitats in Jenin district, in the period from June to November 1998 *.

Site of the trap	No. of night trap	Mean No. / trap / night	St. Deviation No. / trap / night	Maximum No. / trap / night
Indoors	58	20	28	123
Outdoors	40	25	49	264
Animal Sheds	9	38	27	92
Greenhouse	1	-	-	-

- Collection nights at the end of sandfly season were not included.

Sticky traps collected 1185 sandflies, including 10 species in 57 nights, from domestic and agricultural and wild land habitats. The density of sandflies was higher in agricultural land (almond and olive trees) than other habitat, while the maximum catches were in domestic habitat outdoors. The differences in density between domestic and agricultural areas were very clear in the same habitats in olive and almond trees (Table 3. 16).

Knocked down method was carried out 10 times in six localities during the study. Table 3.17 shows sandfly species collected by this method and the mean number of sandfly species per room. Aspiration and human landing techniques were discussed before.

Table 3. 16 The mean of sandfly density (No. / m² / night) collected by sticky traps from different habitats in Jenin district during August and September 1999.

Site of the trap	Domestic habitat				Wild and agricultural lands habitat			
	No. of night trap	Mean of No. / m² / night	S. Deviation No. / m² /night	Maximum No. / m² / night	No. of night trap	Mean No. / m² / night	St. Deviation No. / m² / night	Maximum No. / m² / night
Indoors	4	8.5	7.5	19	-	-	-	-
Outdoors	8	56	119	350	-	-	-	-
Animal Shads	4	3.5	1.3	5	-	-	-	-
Stone heaps	4	7	6	13	4	46	27.5	84
Olive trees	6	6.3	5.5	15	7	50	88	241
Almond trees	-	-	-	-	6	92	122	285
Oak trees	-	-	-	-	6	2.5	2.3	6
Fallow field	-	-	-	-	6	16	18	50
Pine trees	-	-	-	-	4	0	0	0
Green house	-	-	-	-	2	0	0	0

Table 3. 17 Number and mean (per room) of sandfly species collected inside houses by knocked down method from Jenin district.

Species	No. of sandflies	Mean of No. of sandflies / room
P. major	4	0.4
P. papatasi	51	5.1
P. perfiliewi	2	0.2
P. sergenti	6	0.6
P. tobbi	5	0.5
S. tiberiadis	2	0.2
Total	70	7

CHAPTER FOUR

DISCUSSION

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DISCUSSION

Sound knowledge of the biology and ecology of sandflies will help planning appropriate control strategies against leishmaniasis and other diseases. The present study aimed to give baseline guidance to further studies on the sandfly at one of the most important foci of CL and VL in Jenin district, West Bank. A special emphasis was given in the study to recent VL focus at Siris village, which lies in the southern parts of the district where most ecological aspects have been studied.

Leishmaniasis is known to occur in Jenin district for the last two decades. However, information about the disease epidemiology and the role of different sandfly species is almost lacking. An attempt was therefore made in the present study to investigate the sandfly species prevalent in the district and describe some of their ecological habitats, population dynamics and their role in leishmaniasis transmission.

Five collection methods were used in this study. Light trap was the main collection method. 2559 specimens were collected by this method, including all species identified in the study except two, *S. christophersi* and *S. tiberiadis*. Sticky traps were the second main method caught 1185 sandflies including 10 species. This indicates that light trap is more effective method for sandfly collection than sticky traps. This is in contrast to what Lane *et al.* (1988) found and what El Said (1986) found that *P. Papatasi* is negatively phototrophic.

Since sticky trap technique for sandfly collection is not biased, the number of each species of sandfly collected by this method from the same habitat is considered representative. Other collection methods are used for special purposes, namely aspiration method is used to detect diurnal resting sites, human landing is used to determine species of human-biting sandfly and their activity time, and knockdown collection is used to find sandfly species resting indoors during day time (WHO, 1984).

Thirteen sandfly species (9 *Phlebotomus* and 4 *Sergentomya*) were found in all 23 localities in which leishmaniasis has been recorded (Abdeen *et al.*, unpublished work). Few numbers of sandflies were collected from some localities. This may be attributed to small number of sampling times at these localities and probably conditions were not favorable. However during this study there was one fixed location in Siris Village, where sandflies were collected regularly every 8 to 10 days from indoors and outdoors, using two light traps fixed in of the same sites of one house located between 3 houses of VL patients. Other collection methods were used occasionally, and other houses were examined. Nine species of sandflies were found in this village. Another 4 species were found in other localities but were not found in Siris village. This indicates that these species are surely absent from the village area. The absence of some species, found in the Jenin district, from some localities may be attributed to small number of sampling times carried out at these localities (table 3.2). Also the number of sandflies per trap night caught from different localities can not be compared because they were collected at different times under different climatic conditions.

Since the western parts of the district characterized with their high rainfall were not covered well in this study, it is expected that further work in these parts may reveal other sandfly species to those detected in the area.

This is the first report of *P. (Synphlebotomus) sp.* from the area and neighboring countries. Other sandfly species found in Jenin district in this study were reported also from Israel, Jordan and other neighboring countries (Lane *et al.* 1988).

Another important feature of sandflies collection in Jenin district was the occurrence of many species in the area, and even in small localities. Some species were found in very small numbers, because of their scarcity in the area or of some limitation of the collection method, although first reason is more likely.

Phlebotomus species were dominant in human habitation comprising 65% of all sandflies collected from different localities in the district. In agricultural and wild lands, away from domestic habitats, on the other hand, *Sergentomya* species were the dominant species comprising 92 % of all sandflies collected. In domestic habitats these species were found in large numbers at outdoors. These observations are in agreement with the findings of Quate (1964) and Lane *et al.* (1988) who found *Sergentomya* species to be more adapted to open and dry habitats than *Phlebotomus* species.

The relative proportion of *Phlebotomus* species found in this study was different from that found by Schlein *et al.* (unpublished work). This may be due to small number of sandflies collected by Schlein from many places in various northern and central regions in Israel.

The present study has also revealed that species distribution has a tendency for more species to occur at human habitation (13 species, 9 *Phlebotomus spp.*, and 4 *Sergentomya spp.*) than in agricultural and wild lands (5 species, 4 *Phlebotomus spp.*, and 1 *Sergentomya spp.*) (Tables 3.3 & 3.4). This might indicate that human habitation has more breeding sites (moist soil, manure and other organic matters) and presence of host animals and shelters in animal sheds, human dwellings, stone heaps and vegetation.

Sergentomya theodori is the most common species in 10 localities and in agricultural and wild land habitats. It was more prevalent outdoors, comprising about 49.7 % of all collected sandflies. This species is known to prefer dry and open habitats. However, its abundance in human habitats in this work might be due to the fact that these habitats were located mainly at the periphery of the surveyed sites, and where most leishmaniasis cases were found. This species was found to bite human, sometimes outdoors. Other species of the genus *Sergentomya* were also found by Adler *et al.*, (1957) to feed on mammals and reptiles in tropical areas.

The other abundant sandfly species include *P. perfiliewi* (17.9 %), *P. papatasi* (13.2 %), *P. tobbi* (8.6 %) and *P. major* (8.5 %). Other species were found in few numbers.

Despite its found presence in large numbers in different habitats, *P. perfiliewi* was not found in this study to be a human-biting species. This finding is in agreement with that of Adler *et al.* (1957) who reported this species rarely fed on man and preferred feed on animals, and there fore it is played a role in transmitting parasites between reservoir animals. It also reported to be a proven

vector of VL caused by *Le. infantum* (Killick-Kendrick, 1990). Therefore its occurrence in this in fallow fields and its absence from adjacent almond and olive fields might be due to presence of crevices in the soil of fallow fields which may provide suitable shelters and host animals for this species, and the absence of crevices from other field. However no females were caught from fallow fields in this study, which may remained inside deep cracks in the soil while the males were dispersed mating and sugar meals.

Phlebotomus papatasi occurs in domestic habitats in most countries (e.g. Jordan) (Lane *et al.* 1988). However, it occur in human habitation and it found in few numbers in open areas away from human dwellings In other countries (e.g. Saudi Arabia) (Lewis *et al.*, 1980). Large numbers of this species (400 of 1725) were found at Siris village a focus of VL In this study, where it was only found in domestic habitats. It was the main species found resting indoors during daytime (endophilic domestic species) and the main biting sandfly species. This finding are in agreement with similar findings by El Said (1986) who also found that *P. papatasi* was a highly endophilic species in a focus of VL in Egypt. So *P. papatasi* has a medical importance as a vector of diseases.

P. tobbi was collected from most localities and from domestic and wild habitats. It seems to rest inside houses during daytime, but it is more abundant at animal sheds. This indicates that the species feeds more frequently on animals and less frequently on man. It was considered as a suspected vector of VL in the Mediterranean region (Killick-Kendrick, 1990), and has been supported in this study.

Based on Lewis (1982) keys, sandflies belonging to *P. major* collected in this study were identified under three subspecies *P. major major, P. major*

neglectus and *P. major syriacus*. However, these subspecies were reported by Lane (1987) to be restricted to certain areas. Since these subspecies were reported by Lane (1987) to be overlapped in their distribution, *P. major major* and *P. major neglectus* subspecies, collected in this study, are better deal with as one subspecies *P. major syriacus*.

However, *P. major* was found to feed both on man and dogs and transmit VL in Crete (Adler *et al.*, 1957). This may explains the high proportion of this species in the animals shed at Siris village where two dogs were living near the sheds during the collection period. *P. major neglectus* is a suspected vector of VL caused by *Le. infantum* (Killick-Kendrick, 1990), and *P. m. syriacus* is a proven vector of VL in the Mediterranean (WHO, 1984).

P. sergenti (comprised 1 % of all collected sandflies) is one of the rare species and was only found in human habits, usually in small numbers, and was more abundant at localities where CL has been reported. In Jordan this species occurs at and away from domestic areas species (Lane 1988), and it is a proven vector of CL in Saudi Arabia where it is endophilic species (Al Zahrani *et al.*, 1988; 1997). Killick-Kendrick (1990) has shown that this species was a probable vector of CL caused by *Le. tropica* or *Le. major.* Therefore it can be considered as a suspected vector for CL in Jenin district.

P. mascittii is one of the rare species in the area, and little is known about its ecology (Lewis, 1982). Two subspecies were identified *P. mascittii canaaniticus* and *P. mascittii mascittii.* The first subspecies recorded from the area before and the second recorded from Cyprus, Turkey and other European countries (Lewis, 1982). Overlapping and misidentification also is probable in

this species, as has been the case in *P. major*. The present results show that this species fed on both animals and humans.

S. tiberiadis is one of the rare species caught from two neighboring localities (Table 3.2) at the northern parts of the Jenin district. Two flies of this species were collected indoors during diurnal collection, which indicates that this species may be to some extent domestic.

P. jacusieli is also one of the rare species. More flies were caught outdoors than indoors by using light traps. It has no importance as a vector of diseases (Lewis, 1982).

The presence of P. (*Synphlebotomus*) *sp.* is interesting. One of the three species of this subgenus is a vector of VL caused by *Le. donovani* in Kenya, and *P. (S.) rossi* is a suspected vector of CL caused by unnamed leishmania in Namibia (Killick-Kendrick, 1990). Further studies are needed to define species of this subgenus in the area and to provide more information about the ecology of this species and its role in disease transmission.

S. fallax is a very rare species collected indoors in two localities by light traps.

Only one female of *S. christophersi* was caught by sticky trap fixed at an olive tree in a domestic area. This species was distinguished by cibarium, which has 5 widely spaced pointed and long teeth. This species was not recorded before in neighboring Israel but was reported from southern Jordan (Lane *et al.*, 1988).

Only one male of *P. halepensis* was caught by a light trap fixed in a domestic area (outdoors) in Deir Abu Daif village, which was surveyed once.

Therefore, the scarcity of this species may be suspected. It is also considered to be as suspected and poor vector of VL (Killick-Kendrick, 1990).

None of the dissected females were found to harbor promastigotes in their guts. This might be attributed to the relatively small numbers of females dissected (935 of different 7 species). Also most of these flies were collected from domestic areas and may be far from reservoir animals. Janin *et al.* (1995) found 14 infected female sandflies of 636 sandflies of *P. papatasi* collected from Jordan, but no infected females were found among 1446 of the same species collected from human habitation.

Concerning leishmaniasis transmission the most important sandfly species collected in the area were *P. tobbi, P. perfiliewi, P. major, P. mascittii and P. papatasi.* These species were incriminated as vectors of leishmaniasis in many other countries (Killick- Kendrick, 1990). The first three species were found in this work to be engorged with blood in human houses and in animal sheds. This indicated that they fed both on animals and humans as well as many of them were detected to bite man in the area.

P. papatasi, which is the most probable vector of CL in the district, it is a proved vector of CL caused by *L. major* in Jordan (Janini *et al.,* 1995), and in the western parts of Jordan valley (Schlein *et al.*, 1982) which boarders the study area from the east. It is the main sandfly species, which bites human indoors and outdoors in the area. It is one of the most abundant species in the area. It was found in large numbers indoors and in different habitats in domestic areas. Furthermore it is the most dominant species of all *Phlebotomus* species collected from houses of patients of CL in the district. However it was not considered by Killick-Kendrick (1990) to be a vector of VL caused by *Le.*

infantum because of its taxonomic position and geographic distribution in relation to the occurrence of the disease. In this study *P. papatasi* was collected from all localities infected with VL and found to be the most man biting sandfly in the area were only VL has been prevalent.

P. major syriacus is the probable vector of VL in the area because it fed on man indoors and outdoors and encountered in a large number in animal houses (Table 3.3).

Since a few numbers of many of the collected species were encountered, seasonality for only abundant species was studied (figure 3.3). One marked peak was observed during July through August, for in and outdoors collected flies for three species: *P. papatasi, P. perfiliewi and S. theodori.* Two peaks were observed during July and September through October for outdoors and indoors respectively for *P. tobbi* and *P. major.* The marked drop in number of different sandfly species in June in Siris village may be related to insecticide spraying during this period by health authorities. The insecticide applied was Permethrin, with a residual affect period of few weeks.

Data on the effect of climatic factors on sandfly activity in this study show that low wind velocity increases the number of *P. major* and *P. tobbi* collected from indoors; whereas wind velocity was found to increase the number of *S. theodori* collected from outdoors. However the average of wind velocity during time of collection ranged between 0.44 m / s and 1.4 m / s which didn't affect other biting sandflies especially *P. papatasi.* This is in agreement with findings of Quate (1964) and Roberts (1994).

This study has also demonstrated that low temperatures increase the activity of *P. major* indoor (Table 3.14). However, correlation was found between temperature and relative humidity and other sandfly species.

The earlier occurrence of a peak of abundance of some sandfly species found indoors than outdoors was also observed in Saudi Arabia (Al-Zahrani *et al.* 1997). However, no differences were found, in Saudi Arabia, when only females of suspected vectors were compared. This may indicate that the probability of infection with CL or VL is higher in the first half of the sandfly season outdoors and in the second half of the sandfly season indoors.

Roberts (1994) found that light intensity is the most important factor affecting sandfly activity followed by low humidity, low wind velocity and high temperature. One limitation of this study was that the effect of light intensity especially moon light and cloudiness that were not taken into consideration.

It seems that, at night, as atmospheric temperature drops and relative humidity rises, sandflies leave diurnal resting sites and fly to inside houses where conditions become more favorable. In the morning some species seem to leave houses and rest at outdoor sites and other species like *P. papatasi* kept inside.

Unfortunately sandflies collected from human landing during nights were not separated for different time interval. The most biting species in Siris village was *P. papatasi* (representing 96.5 and 82.2 of all sandflies collected by this method from in and outdoors respectively) so that the time biting activity represent the biting activity for this species. Biting activity was observed at in and outdoors sites from two to three hours after sunset to sunrise and the peak was around 02:30 a.m. and 03:30 a.m. for in and outdoors respectively.

However El Said *et al.* (1986) who found at focus of VL in Egypt that *P. papatasi* was active after midnight; and Mohsen (1983) found that the same species in Iraq shows maximal biting activity around midnight.

El Said *et al.* (1986) found that 55 % of the females of *P. papatasi* entering houses after sunset to midnight were either gravid or half-gravid and 33 % were freshly fed. This explains the high percentage of gravid and freshly fed females of this species caught from outdoors in the study area during their search for a place to rest in including human houses.

The presence of freshly blood fed sandflies of different species inside houses indicates blood feeding habit on human and the same applied for those females collected from animal sheds.

A high proportion of engorged females was observed for *Phlebotomus* species especially *P. papatasi.* Refeeding habits of *P. papatasi* regardless of egg laying (Adler et al. 1957) may explain this high proportion. On the other hand, a very low proportion of engorged females was observed for *Sergentomya* species. This is in agreement with the finding of Schlein *et al.* (1982), who suggested that this phenomenon occurred because these species are highly autogenous.

No gravid females were found in the animals' shed, although many freshly fed females of different species were found. This may be due to conditions of the animal shed, where majority of sandflies were collection from. The ceiling of this shade was made of metal, resulting in high temperatures during the daytime and so unsuitable for sandfly resting.

The examined localities did not vary much in their altitudes, which ranged from 100 to 500 meters above sea level. This might explain the little

differences in sandfly composition at different altitudes. Despite that some species such as *P. papatasi, P. major, P. tobbi* and *P. mascittii* were more dominant at a high of 300-399 meters, *P perfiliewi* was more prevalent at 400-500 meters and *S. theodori* at 100-200 meters. This is in agreement with the findings of Buttiker *et al.* (1983) who found that different sandfly species present at different altitudes *P. major Syriacus* was found at average altitude of 1125 m whereas *P. papatasi* preferred low altitudes ranging from 0 to 750 m.

Collection methods used in the study appear to have been very successful. However, results were somewhat limited by the low catches of some species. This may be attributed to the rarity of some species and the use of one method (sticky traps) in wild and agricultural lands.

In general more females, 66% of the total collection, were caught in this study. Sticky traps collected smaller proportion of females especially of P. papatasi species. On the other hand light traps collected higher proportions, this is in agreement with the findings of Chaniotis *et al.* (1971) who caught more females than males by using light traps. Thus, it is suggested that sex ratio is affected by the collection method used and attraction of sandflies to host(s) found in the surrounding of trap(s).

Although soil type determines water retaining capacity of the soil which in turn affects the breeding conditions of sandflies. The soil types present in Jenin district did not seem to effect on sandfly distribution.

A high number of sandflies, especially members of *Sergentomya* species, was collected from almond field, few numbers were collected from oak forest and none from pine forest. This may be attributed to the difference in attraction of sandflies to various vegetation types. The high abundant of

sandflies around almond trees may be due to sugar feeding behavior as more males were caught by unbiased method (sticky traps) and these trees were infested with aphids. The aphid honeydew was considered as a major sugar source for sandflies. However the attraction of sandflies to different vegetation type may not be for sugar feeding only. Warburg *et al.* (1987) showed that sandflies might be attracted to vegetation for shading, resting and breeding. The mechanism responsible for differential attraction of sandflies to different types of plants is not known (Cameron *et al.*, 1994). The low numbers or absence of sandflies at oak and pine forest may indicate that these trees do not provide suitable sites for shading, resting and breeding or may release volatiles repellent for sandflies.

Parasites infecting sandflies were isolated from many other countries before. Schlein reported three types of mites infecting sandflies in neighboring Israel (Buttiker & Lewis, 1983). Although few numbers of these parasites were found, their incidence may be higher as the mites were found on sandflies after a process of washing which might had removed many mites away. Also worms were observed in a female with its last five segments cut off, the most majority of females were dissected by cutting off the last three segments, and that may have remove the worms present.

There is no indication at present of any parasite, which might be useful in the control of sandflies. However, further studies on mites and nematodes found in this study could be useful in finding out some bio-control agents of sandflies.

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بسم الله الرحمن الرحيم

بيئة و بيولوجيا ذبابة الرمل الفاصدة (رتبة ثنائية الأجنحة: فصيلة Psychodidae)- في بؤر مختلفة لمرض اللشمانيا في محافظة جنين الضفة الغربية فلسطين

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الملخص

يعتبر مرض اللشمانيا أحد المشاكل الصحية المهمة في الضفة الغربية، فلسطين. أجريت هذه الدراسة في محافظة جنين حيث أن معظم بؤر اللشمانيا التي حدثت في الضفة الغربية خلال العقد الأخير تقع في هذه المحافظة. إن توزيع أنواع الذباب الرملي الناقل لمرض اللشمانيا في المحافظة غير معروف. لقد استخدمت عدة أنواع من طرق جمع الذباب الرملي و اشتملت على المصائد الضوئية واللاصقة و الجمع بطريقة الشفط و الجمع من طعم بشري من أجل التعرف على أنواع الذباب الرملي الموجود في المنطقة و إعطاء صورة واضحة لمظاهر مختلفة من علاقة الذباب الرملي في بيئته. تم جمع ٤٠٨٢ حشرة من الذباب الرملي من عدة بؤر ينتشر فيها مرض اللشمانيا الجلدية و / أو الحشوية خلال الفترة من شهر حزيران و كانون الأول من العام ١٩٩٨. تم تحديد ١٣ نوعا و ٧ تحت أنواع varieties تقع ضمن ٧ تحت أجناس من جنسين هما *Sergentomya* و *Phlebotomus* ؛ و كانت الأنواع التي تم تصنيفها على النحو التالي:

P. (Larroussius) perfiliewi transcaucasicus, P. (L.) tobbi, P. (L.) mascittii mascittii, P. (L.) major syriacus, P. (Phlebotomus) papatasi, P. (Synphlebotomus) sp., P. (Paraphlebotomus) sergenti sergenti, P. (Pa.) jacusieli, P. (Adlerius) halepensis, S. (Sergentomya) theodori, S. (S.) fallax, S. (Sintonius) tiberiadis, S. (Sin.) christophersi.

هذا بالإضافة إلى تحت نوعين يحتاجان إلى المزيد من الدراسة والتأكيد هما *P. (L.) m. major* و *P. (L.) m. neglectus*. من بين الأنواع السابقة الذكر فإن سبع أنواع لا يمكن استبعادها كحشرات ناقلة أو لها دور في انتشار مرض اللشمانيا مما يشير إلى زيادة احتمال الإصابة بالمرض في المحافظة. اعتبر النوع *P. papatasi* هو الأكثر احتمالا أن يكون ناقلا لمرض اللشمانيا الجلدية في المحافظة وذلك لأنه يشكل نسبة عالية من ذباب الرمل الموجود في بيئة الإنسان و خاصة من داخل منازل المصابين بمرض اللشمانيا الجلدية، كما أن هذا النوع هو النوع الرئيسي الذي يلدغ الإنسان في المنطقة ؛ كما وجد أن النوع الأكثر احتمالا كناقل لمرض اللشمانيا الحشوية هو *P. m. syriacus* حيث وجد هذا النوع بكثرة في حظائر الحيوانات وهو يتغذى على الإنسان والحيوانات. و تعتبر هذه هي المرة الأولى التي يسجل فيها وجود نوع من تحت جنس *Synphlebotomus* في الضفة الغربية و الدول المجاورة.

من بين خمسة أنواع وجدت تلدغ الإنسان وجد أن *P. papatasi* تشكل ٩٠ % يتبعها *P. major* ٨ % والأنواع الثلاثة الأخرى وهي *P. tobbi* و *P. mascittii* و *S. theodori* تشكل ٢ % ، وجد أن نشاط اللدغ يحدث طوال ساعات الليل ويتركز خلال ثلاث إلى أربع ساعات بعد منتصف الليل. وجد أن حشرتين من الذباب الرملي من نوع *P. papatasi* و *P. sergenti* مصابتان بالحلم mite وحشرة أخرى من نفس النوع الأول مصابة بديدان . وقد تم وصف و توضيح جميع أنواع الذباب الرملي التي جمعت خلال هذه الدراسة.

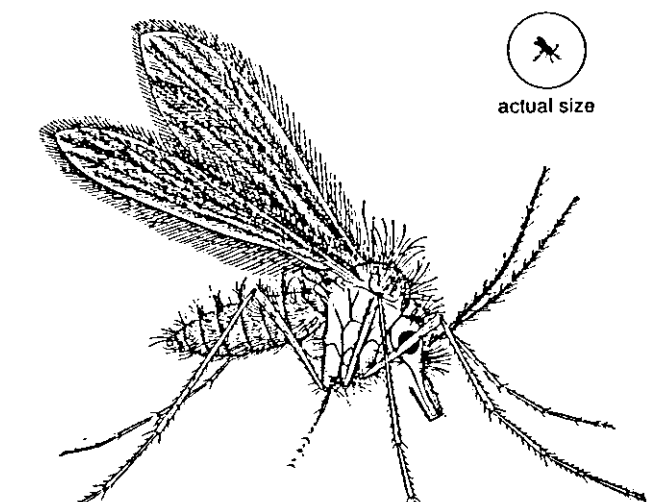

Fig.
Phlebotomine sandfly. About 1.3–3.5 mm in length; hairy appearance; conspicuous black eyes; long, stilt-like legs (by courtesy of the Natural History Museum, London).