Spatial Correlation Between *Phlebotomus papatasi* Scopoli (Diptera: Psychodidae) and Incidence of Zoonotic Cutaneous Leishmaniasis in Tunisia

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ABSTRACT The geographical distribution of *Phlebotomus papatasi* Scopoli, vector of *Leishmania major* Yakimoff and Schokhor (Kinetoplastida: Trypanosomatidae), the etiologic agent of zoonotic cutaneous leishmaniasis (ZCL), was assessed during September 2006 through a transect from the north to the south of Tunisia using CDC light traps. *P. papatasi* was found to be abundant in the arid and Saharan bioclimatic zones and rare in the humid, subhumid, and semiarid bioclimatic zones. Similarly, the highest incidence of ZCL was observed in the arid and Saharan bioclimatic zones and the lowest in the humid, subhumid, and semiarid bioclimatic zones. Our overall findings confirm the close spatial association between the abundance of *P. papatasi* and the incidence of ZCL.

KEY WORDS sand fly, *Phlebotomus papatasi*, abundance, spatial distribution, zoonotic cutaneous leishmaniasis

Zoonotic cutaneous leishmaniasis (ZCL), endemic in central and southern Tunisia (Ben Ismail 1993), is caused by *Leishmania major* Yakimoff and Schokhor (Kinetoplastida: Trypanosomatidae), which is transmitted by the sand fly *Phlebotomus papatasi* Scopoli (Ben Ismail et al. 1987a). In Tunisia, the fat sand rat *Psammomys obesus* Cretzchmar is the principal reservoir of *L. major* (Ben Ismail et al. 1987b, Fichet-Calvet et al. 2003). During the transmission season of 2005–2006, >9,000 cases of ZCL were reported to the National Health Department.

A study conducted during the summer of 1980 to trap sand flies in a transect from the north to the south of Tunisia showed that the distribution of *P. papatasi* was related to the arid and Saharan bioclimatic areas (Rioux et al. 1986). It is therefore of major epidemiological importance to repeat this transect study after 25 yr to update the geographical distribution of *P. papatasi* and to examine its relationship to the distribution of ZCL.

Materials and Methods

Tunisia covers a wide climatic range from humid in the north to the dry Saharan climate in the south (Fig. 1). Sand flies were sampled at six sites within different bioclimatic zones varying from humid to Saharan (El Jouza, 36°86′ N, 6°68′ E, humid; Utique, 37°08′ N, 7°74′ E, subhumid; Mjez El Bab, 36°45′ N, 6°09′ E, upper semiarid; Maktar, 35°52′ N, 9°12′ E, lower semiarid; Sidi Bouzid, 34°51′ N, 9°29′ E, arid; Douz, 33°29′ N, 9°03′ E, Saharan). Sand flies were collected inside houses and in animal shelters located in the peridomestic areas using CDC light traps (one inside a house and one in an animal shelter were placed from dusk to dawn one night per site during September 2006). Collection of sand flies was performed during the second and the third week of September based on the fact that the major peak of activity of several sand fly species in Tunisia and in surrounding countries occurs during this period: *P. papatasi* (Chelbi et al. 2007), *Phlebotomus perniciousis* Newstead, *Phlebotomus perfiliewi* Parrot (Croset et al. 1978), *Phlebotomus longicuspis* Nutzulescu (Croset et al. 1978), and *Phlebotomus langeroni* Nutzulescu (Beier et al. 1986). Collected sand flies were placed in 70% ethanol and later mounted on glass slides in Mark André medium (Abonnenc 1972) and identified to species level by using the identification keys of Croset et al. (1978). The abundance of *P. papatasi* was recorded as the number of *P. papatasi* divided by the total number of sand flies caught per bioclimatic zone. Correlation between the abundance of *P. papatasi* and incidence of ZCL by bioclimatic zones was computed using two methods: Spearman (Best and Roberts 1975) and Kendall (Hollander and Wolfe 1973). These are two nonparametric (distribution-free) measures of monotony and association, respectively, between two random variables, using converted raw scores to ranks.

All data from clinically confirmed ZCL cases were obtained from the National Health Department for the period of July 2005 to June 2006 (DNSSB 2006). The geographical distribution of ZCL cases by bioclimatic zones for this period is reported in this study.

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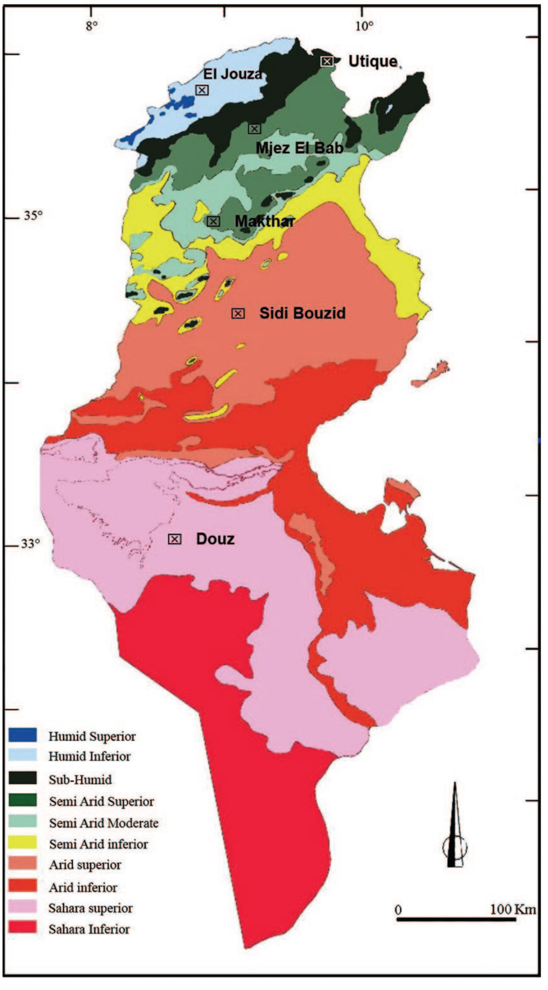

Fig. 1. Bioclimatic map of Tunisia.

Results and Discussion

During the study period, 2,086 sand flies were collected. Eleven species were identified: eight *Phlebotomus* spp. and three *Sergentomyia* spp. The abundance of each species by bioclimatic zone is shown in Table 1. *P. papatasi* was rare in the humid, subhumid, and semiarid bioclimatic zones and became abundant in the arid and Saharan bioclimatic zones. The results of 1980 study showed that densities of *P. papatasi* (number of *P. papatasi*/m^2 of sticky traps) in the humid, subhumid, semiarid, arid, and Saharan bioclimatic zones were 0.0, 0.06, 0.01, 0.98, and 1.15, respectively (Rioux et al. 1986). Therefore, compared with 25 yr ago, there seems to have been no extension of the range of *P. papatasi* from the arid toward the semiarid, subhumid, or humid bioclimatic zones located in the northern parts of Tunisia. However, a clear extension of the geographical distribution of human visceral leishmaniasis from the north toward the center and the south of Tunisia has occurred during the last 25 yr (Ben Salah et al. 2000). Environmental changes, particularly the development of irrigation systems in the arid and Saharan bioclimatic zones, may have increased the availability of a more humid habitat, thus extending the ranges of *P. perfiliewi*, *P. perniciosus*, *P. langeroni*, and *P. longicuspis*, vectors of *L. infantum*, toward the center and south of Tunisia, resulting in the emergence of new foci of human visceral leishmaniasis in these areas (Zhioua et al. 2007). The geographical distribution of *P. papatasi* is related to bioclimatic factors (Rioux et al. 1986). Increased humidity seemed to be a limiting factor for the geographical extension of *P. papatasi*, because the abundance of this species increased with the aridity. Similar results were reported for Morocco (Rioux et al.1984, 1997) and India (Singh 1999). In Tunisia, *P. obesus* is distributed in the arid and Saharan bioclimatic zones (Ben Ismail et al. 1987b, Fichet-Calvet et al. 2003, Ben Hamou et al. 2006). Therefore, both the vector and the reservoir are abundant in the arid and the Saharan bioclimatic zones.

During the transmission season of 2005–2006, 9,030 confirmed cases of ZCL were reported to the National Health Department (Table 2), of which 7,631 (84.5%)

Table 2. Abundance of *P. papatasi* and incidence of ZCL cases during the transmission season of 2006 per bioclimatic zone

Bioclimate	Abundance of *P. papatasi* [% (total *N* of sand flies)]	No. ZCL cases (human population)	Incidence (100,000 inhabitants)
Humid	0.2 (467)	0 (433,300)	0.0
Subhumid	2.9 (134)	0 (3,873,300)	0.0
Semiarid	1.3 (360)	159 (1,492,000)	0.1
Arid	62.7 (1,024)	7,631 (3,285,000)	2.3
Saharan	33.6 (101)	1,240 (823,000)	1.5

Table 1. Diversity and abundance (%) of sand flies caught by CDC light traps, Tunisia, September 2006

Species	Humid	Subhumid	Upper semiarid	Lower semiarid	Arid	Saharan
P. papatasi	1 (0.2)	4 (3)	5 (2)	0	642 (62.7)	34 (33.6)
P. perfiliewi	429 (91.8)	35 (26.1)	11 (4.5)	24 (20.6)	50 (4.9)	0
P. perniciosus	31 (6.6)	80 (59.7)	215 (88.1)	69 (69.4)	204 (19.9)	0
P. longicuspis	0	0	0	10 (8.6)	8 (0.8)	61 (60.4)
P. alexandri	0	0	0	0	30 (2.9)	0
P. langeroni	0	0	0	11 (9.5)	0	0
P. sergenti	0	0	0	0	5 (0.5)	0
P. chadlii	0	0	0	0	1 (0.1)	0
S. minuta	6 (1.3)	15 (11.2)	13 (5.3)	2 (1.7)	16 (1.5)	6 (5.9)
S. fallax	0	0	0	0	50 (4.9)	0
S. dreyfussi	0	0	0	0	18 (1.7)	0
Total	467	134	244	116	1024	101

and 1,240 (13.7%) were observed in the arid and Saharan bioclimatic zones, respectively. The remaining cases were reported from the semiarid bioclimatic zones. It is important to point out that cases of ZCL ($N = 159$) reported from the semiarid bioclimatic zones are in fact from the lower parts close to the arid areas. Incidence rates of ZCL per 100,000 inhabitants in the humid, subhumid, semiarid, arid, and Saharan bioclimatic zones were 0.0, 0.0, 0.1, 2.3, and 1.5, respectively (Table 2). In fact, ZCL is highly endemic in arid and Saharan bioclimatic zones. The disease is quasi-absent in the humid and subhumid zones and rare in the semiarid bioclimatic zones.

Our results showed that the incidence of ZCL is closely related to the abundance of *P. papatasi.* Values of Kendell's τ and Spearman's ρ statistics and respective one-side P values relative to the null hypothesis of no correlation were 0.73786, 0.820 and 0.038, 0.044. Clearly, there is a close spatial association between the abundance of *P. papatasi* and the incidence of ZCL. Thus, the abundance of *P. papatasi* could be used as a crude indicator of the risk of ZCL in a given bioclimatic zone. Our findings strongly suggest the importance of the bioclimate on the distribution and the abundance of *P. papatasi* and, in the presence of animal reservoirs, subsequently on the distribution and the force of infection of corresponding foci of ZCL (Rispail et al. 2002).

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References Cited

Abonnenc, E. 1972. Les phlébotomes de la région éthiopienne (Diptera, Psychodidae). Mém. ORSTOM. 55: 289.

Beier, J. C., B. M. El Sawaf, A. I. Merdan, S. El Said, and S. Doha. 1986. Sand flies (Diptera: Psychodidae) associated with visceral leishmaniasis in El Agamy, Alexandria Governorate, Egypt. J. Med. Entomol. 23: 600–608.

Ben Hamou, M., S. Ben Abderrazek, S. Frigui, N. Chatti, and R. Ben Ismail. 2006. Evidence for the existence of two distinct species: *Psammomys obesus* and *Psamomys vexillaris* within the sand rats (Rodentia, Gerbillinae) reservoirs of cutaneous leishmaniasis in Tunisia. Infect. Genet. Evol. 6: 301–308.

Ben Ismail, R. 1993. Recueil des données épidémiologiques quantitatives de base dans un foyer pilote de leishmaniose cutanée zoonotique. Arch. Inst. Pasteur Tunis 70: 91–110.

Ben Ismail, R., M. Gramiccia, L. Gardoni, H. Helal, and M. S. Ben Rachid. 1987a. Isolation of *Leishmania major* from *Phlebotomus papatasi* in Tunisia. Trans. R. Soc. Trop. Med. Hyg. 81: 749.

Ben Ismail, R., M. S. Ben Rachid, L. Gardoni, M. Gramiccia, H. Helal, and D. Bach-Hamba. 1987b. La leishmaniose cutanée zoonotique en Tunisie; étude du réservoir dans le foyer de Douara. Ann. Soç. Bel. Méd. Trop. 67: 335–343.

Ben Salah, A., R. Ben Ismail, F. Amri, S. Chlif, F. Ben Rzig, H. Kharrat, H. Hadhri, M. Hassouna, and K. Dellagi. 2000. Investigation of the spread of human visceral leishmaniasis in central Tunisia. Trans. R. Soc. Trop. Med. Hyg. 94: 382–386.

Best, D. J., and D. E. Roberts. 1975. Algorithm AS 89: the upper tail probabilities of Spearman's rho. Appl. Stat. 24: 377–379.

Chelbi, I., M. Derbali, Z. Al-Ahmadi, B. Zaafouri, A. El Fahem, and E. Zhioua. 2007. Phenology of *Phlebotomus papatasi* (Diptera: Psychodidae) relative to the seasonal prevalence of zoonotic cutaneous leishmaniasis. J. Med. Entomol. 44: 385–388.

Croset, H., J. A. Rioux, M. Master, and N. Bayar. 1978. Les phlébotomes de la Tunisie (*Diptera*, Phlebotominae). Mise au point systématique, chorologique et éthologique. Ann. Parasitol. Hum. Comp. 53: 711–749.

[DNSSB] Direction Nationale de Soin de Santé de Base. 2006. Ministere de la Sante Publique. Bull. Epidémiol. 3: 9.

Fichet-Calvet, E., I. Jomâa, R. Ben Ismail, and R. W. Asford. 2003. *Leishmania major* infection in the fat sand rat *Psammomys obesus* in Tunisia: interaction of hosts and parasite populations. Ann. Trop. Med. Parasitol. 97: 593–603.

Hollander, M., and A. D. Wolfe. 1973. Non-parametric statistical inference. Wiley, New York.

Rioux, J. A., P. Rispail, G. Lanotte, and J. Lepart. 1984. Relations phlébotomes-bioclimats en écologie des leishmanioses. Corollaires épidémiologiques. L'exemple du Maroc. Bull. Soc. Bot. Franç. 131: 549–557.

Rioux, J. A., G. Lanotte, F. Petter, J. Dereure, O. Akalay, F. Pratlong, I. D. Velez, N. B. Fikri, R. Maazoun, M. Denial, D. M. Jarry, A. Zahaf, R. W. Ashford, M. Cadi-Soussi, R. Killick-Kendrick, N. Benmansour, G. Moreno, J. Périères, E. Guilvard, M. Zribi, M. F. Kennou, P. Rispail, R. Knechtli, and E. Serres. 1986. Les leishmanioses cutanées du bassin Méditerranéen occidental, de l'identification enzymatique à l'analyse éco-épidémiologique. L'expemple de trois ≪foyers≫ tunisien, marocain et français. *In* : *Leishmania.* Taxonomie et Phylogénèse, pp. 471–478. *In* Applications éco-épidémiologiques. International Colloquium CNRS/ INSERM, (Juillet, 1984). IMEEE, Montpellier.

Rioux, J. A., O. Akalay, J. Perieres, J. Dereure, J. Mahjour, H. N. Le Houerou, N. Leger, P. Desjeux, M. Gallego, A. Saddiki, A. Barkia, and H. Nachi. 1997. L'évaluation éco-épidémiologique du ≪risque leishmanien≫ au Sahara atlantique marocain. Intérêt heuristique de la relation ≪phlébotomes - bioclimats≫. Ecol. Mediter. 23: 73–92.

Rispail, P., J. Dereure, and D. Jarry. 2002. Risk zones of human leishmaniases in the Western Mediterranean Basin. Correlations between vector sand flies, bioclimatology, and phytosociology. Mem. Ins. Oswaldo Cruz 97: 477–483.

Singh, K. V. 1999. Studies on the role of climatological factors in the distribution of phlebotomine sandflies (Diptera : Psychodidae) in semi-arid areas of Rajasthan, India. J. Arid Environ. 42: 43–48.

Zhioua, E., B. Kaabi, and I. Chelbi. 2007. Entomological investigation following the spread of visceral leishmaniasis in Tunisia. J. Vector Ecol. 32: 371–374.

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