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Review of medical arthropods in Tunisia

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Abstract
The influence of arthropods on human and animals health exceeds the importance that entomologists attribute to them because of their abundance and diversity. The aim of this study is to review the medical arthropods in Tunisia in order to implement an effective and permanent surveillance. Nine important medical arthropods exist in Tunisia: scorpions, bed bugs, ticks, cockroaches, scabies, fleas, lice, sandflies and mosquitoes. We discussed their medical interest and geographic distribution based on available data. Provide recommendations for research and surveillance that should be prioritized in order to prepare the country for future public health challenges were suggested. Stress that all challenges are international, because the vectors spread across borders.

Keywords: medical arthropods, research, surveillance, recommendations, Tunisia

1. Introduction
The influence of arthropods on humans and animals health exceeds the importance that entomologists attribute to them because of their abundance and diversity. Their wealth in Tunisia is linked to particularly favorable climatic and biogeographical conditions. Tunisia's climate is divided into five bioclimatic zones, the great difference between the north and the rest of the country being due to the Tunisian ridge that separates the zones subject to the Mediterranean climate from those subjected to the hot desert climate typical of the Sahara (Figure 1). Between the two, there is the warm semi-arid climate with characteristics common to the two main climate regimes of the country (Figure 1). Tunisia is urbanized to 64,9% (2005) and knows an annual rate of urbanisation of 3,6%. The urban network is on the Eastern littoral tape, between the areas of Bizerte and Gabes via Tunis, the Cap bon, the Sahel and Sfax, which has greatest economic infrastructures and concentrates more than 80% of the urban population (Figure 2).
Entomologists in tropical regions, particularly in Tunisia, are confronted with the epidemiological problems of the transmission of pathogens by haematophagous or transporters arthropods; it is in addition of the presence of nuisance, allergenic, or parasites arthropods.
This review is intended primarily for decision-makers and the public to raise awareness of the value of arthropod vectors as a heritage value and source of information for vector control and public health. This review is also aimed to vector control agents to inform them of the existence of these resources and to give them the keys to use them. Finally, this synthesis is also written for institutions and researchers who wish to improve the management of their existing collection.
The aim of this study is to review the medical arthropods in Tunisia in order to implement an effective and permanent humans and animals surveillance. Provide recommendations for research and surveillance that should be prioritized in order to prepare the country for future public health challenges were suggested.

2 Medical arthropods in Tunisia
2.1 Scorpions
We record 30 000 scorpion bites per year in Tunisia (Hamouda and Ben Saleh, 2010) [14]. One to 2% of these bites evolve as severe forms, with cardio-respiratory manifestations requiring management in resuscitation. The decrease in mortality could only be achieved through the development of Tunisian medical research. The scorpions live in colonies under the stones and in the small cavities of the soil. They dig real burrows in the vicinity and even in the houses. The scorpion is a nocturnal animal. It is only active during the hot season. It leaves its shelter at dusk in search of freshness, food and water.

The toxicity of the venom depends on the variety, size, age, nutrition and climatic conditions in which the scorpion lives. The venom of the scorpion is thermostable, resistant to vacuum desiccation and its toxicity is preserved for several years. Scorpion venom consists of toxic proteins (neurotoxins) and hemolymph.

Scorpions are found throughout Tunisia (Table 1). Four species are commonly found: *Androctonus australis*, which is 10 to 12 cm tall, straw yellow, the ends of the tongs and tail are darker, the tongs are elongated, the tail is thick and concave. It is a country species that has a tendency to domestication. It is found in the Tunisian center (south of a line linking Sousse to Gafsa), southern Tunisia and the southern islands (Djerba and Kerkennah). *Androctonus aeneas* which measures 8 cm, black color, the clamps are very fine. This species is less common. It is found in the center and south of Tunisia, mainly on the high plateaus. *Buthus occitanus*, which is 5 to 8 cm tall, yellow, much more prevalent than the previous ones. This species includes two sub-species: *Buthus Occitanus Paris* spread north and *Buthus occitanus Tunetanus* which rages in the center and south. The latter may be responsible for serious forms. *Scorpio maurus* is small and harmless. Their power haemolytic of its venom is not found in other species. It is quite widespread in the center and north Tunisians.

2.2 Bed bugs

Bed bugs, *Cimex hemipterus* (tropical species) and *Cimex lectularius (*ubiquitous species) have been extinct from decades but some cases were recorded each year in Tunisia (Table 1). The data were not documented. These animals require blood for the development of their nymphs, their subsequent stages (Johnson, 1941) [29] and for the reproduction of their adults. A female can produce 5-7 eggs per week with a mean of 200-500 eggs throughout her life. The adult can survive several years without blood meals (Pinto *et al*., 2007) [38]. Many studies showed that Bed bugs live in cracks and crevices around bed or wooden furniture in hotels, hostels, private homes, trains, and cruise ships (Delaunay *et al*., 2011) [19] and they have the ability to spread from shelter to shelter (Stephen *et al*., 2005) [41]. They are known to bite and feed on human blood at night. Bed bugs cause intense itch, inflammation, allergic symptoms and psychological effects (O'Neill *et al*., 1997a, Doggett and Russell, 2009) but they do not transmit diseases to humans (Dolling, 1991) [22].

2.3 Ticks

Tick bites are able to transmit disease and cause skin irritation. The most known disease that can transmit it is the Lyme which attack the nervous system of both animals and humans. Fourteen species were identified in Tunisia (Bouattour *et al*., 1999) [9]. The most important and abundant was *Hyalomma detritum detrium* species infesting cattle. Two species were collected on domestic ruminants in the arid and desertic zones: *Hyalomma dromedarii* and *Hyalomma impeltatum. Hyalomma marginatum marginatum* and *Hyalomma anatolicum excavatum* were found essentially on livestock hosts. Same authors showed the colonization of *Ixodes ricinus* in the humid zone. The sub-humid and semi-arid zones are the preferred environments of *Boophilus annulatus* and *Rhipicephalus bursa* infesting cattle, sheep. Cattle and sheep of humid and sub-humid zones were colonized by *Haemaphysalis sulcata* and *Hae. Punctata*. *Rhipicephalus turanicus*is can live on different animal species in different regions. *Rhipicephalus sanguineus*is known as the ticks of dogs and mainly found on livestock. *Hyalomma marginatum rufipes* and *Hyalomma franchinii* were present in Tunisia with a low abundance. There is no recent research on the taxonomic revision of this arthropod and its distribution in Tunisia. These species exist throughout the Tunisian territory (Table 1).

2.4 Cockroaches

Cockroaches are commonly found in commercial premises used for the production or handling of foodstuffs, but also in public buildings and dwellings such as apartment blocks. Cockroaches represent potential vectors of diseases such as dysentery, gastroenteritis, typhoid fever and poliomyelitis.

Four species have been identified and published in Tunisia (Ben M'rad *et al*., 2004) [7]. Cockroaches are found throughout Tunisia (Table 1). Four species are frequently found: Eastern blight (*Blatta orientalis*) of length: 20-24 mm in adulthood; Color: brown-black, almost black; The wings of the males cover two-thirds of the abdomen, those of the females are atrophied; Can climb only on rough vertical surfaces. Germanic Blattella (*Blattella germanica*) 10-15 mm long in brown yellowish adult age, with two longitudinal marks of black color on the pronotum; The wings of both sexes are well developed; Can easily climb on rough or polished vertical surfaces. American cockroach (*Periplaneta americana*) 28-44 mm long at brown-red adult age, with a yellow border around the pronotum; No marginal yellow stripes on the anterior wings; Last segment of the cirque twice as long as wide. Australian cockroach (*Periplaneta australasiae*) 30-35 mm long in light brown adult age, with a yellow-ivory circular band surrounding a large marked black spot, double lobe; Marginal yellow stripe at the base of the anterior wings. Striped cockroach (or furniture) (Supella longipalpa) of length 9-14 mm in adulthood, resembles the Germanic cockroach with which it is often confused. With the exception of the study of Ben M'rad *et al*. (2004) [7], there is no research on the taxonomic revision of this arthropod and its distribution in Tunisia. These species exist throughout the Tunisian territory and probably there are no preferences at a particular bioclimatic stage (Table 1).

2.5 Scabies

Sarcoptes scabiei is an ectoparasite which affect contagious infestation in both animals and humans called scabies (Chosidow, 2006 [13]; Hengge *et al*., 2006 [27]; Currie *et al*., 2010 [16]; Walton *et al*, 2007 [46]; Currier *et al*., 2011) [17]. This disease caused an important public health problem in the world and characterized mainly developing countries (Alasaad *et al*., 2013 [3]; Hay *et al*., 2012) [26]. In 2010, >100 million cases was recorded on humans in the world (Hay *et al*., 2014). This ectoparasite has also a veterinary interest on wild and domestic animals. Authors indicated that 104 of mammalian hosts worldwide were affected including companion, livestock and wild animals (Currier *et al*., 2011 [17]; Alasaad *et al*., 2013 [3]; Holz *et al*., 2011) [28].

Young children are very exposure to scabies mainly due to the lack of immunity. Both sexes were affected similarly. This ectoparasite is very associated to poverty, poor hygiene and socioeconomic and behavioural factors (Walton *et al*., 1999 [47]; Badiaga *et al*., 2005 [5]; Tsutsumi *et al*., 2005) [45].

Outbreaks frequently occur in institutions such as hospitals, nursing homes, prisons, or kindergartens. In Tunisia, this disease was ubiquitous and currently there are not *scabei sacoptes* except a few sporadic cases in prisons and schools (Table 1).

2.6 Fleas

Flea is an insect belong to the order of Siphonaptera. It is an hematophagous ectoparasites and transmit many pathogens to both humans and animals. Authors described over than 2500 species of flea, belonging to 16 families and 238 genera (Lewis 1998). Despite this important number, just a minority of Fleas are associated to humans (synanthropic). We cited mainly *Ctenocephalides felis* (cat flea) collected from Tunisia (Khrouf *et al*., 2014). In Tunisia, unfortunately no scientific reports were recorded about the diversity of this arthropod and its geographic distribution (Table 1).

2.7 Lice

Lice is a good example of neglected endemic parasite diseases in developing countries and that's why it it is not prioritised in the implementation of control programs. Parasite infestation does not cause patent health problems for farmers, field veterinarians and decision-makers in animal health because the losses to farmers are vey low. Despite the low losses, the accumulation of the number of infested animals and the various infectation rates give it an importance interest. In fact, Byford *et al*. (1998) estimated a 9.2% decrease in average daily weight gain as a result of pediculosis. Taking account of the reduction in milk yield and a decrease in the quality of leather, Kunz *et al*. (1981) [32] showed in 1961 that the annual losses due to pediculosis in the cattle industry in the United States reached US$126.3 million. In developing countries, just some epidemiological studies were done on Lice because of animals are challenged by other more important diseases and lack of financial ressources to control animal diseases by farmers.

In 1909, the director of the Pasteur Institute of Tunis, Nicolle (1866-1936) demonstrated the role of the louse in the transmission of typhus, thanks to which he received the Nobel Prize for Medicine in 1928. This parasite is therefore the vector of disease responsible for millions of deaths and there is still no effective treatment on that date. Of the six families recognized by most specialists, only one, Pediculidae, parasites humans. Among this family, two genera are strictly subservient to humans: Pediculus and Phtirius. For Pediculus, some authors speak of two different species for the head louse and the body louse. However, recent studies classify these two lice into two varieties of the same species. In the genus Pediculus, there are therefore: *Pediculus humanus*, variety humanus, Linnaeus, 1758 also called *Pediculus corporis*; *Pediculus humanus*, variety capitis, De Geer, 1778: head louse. The genus Phtirius comprises only one species, but several spellings: Phthirius, Phthirus, Phtirius and Phtirus. In their reference works, published in 1955 and 1985 respectively, Mathis and Valade write Phtirus. But as the most recent publications mention Phtirius pubis: *Phtirius pubis*, Leach, 1815: pubis or morpion, also called *Phtirius inguinali*.

In Tunisia, Lice disappeared sine a long time like announced Tunisian Ministry of Health actually. In contrast, 16 students of Bousalem, governorate of Jendouba, caught lice after the revolution (Table 1).

2.8 Sandflies

The sandflies (Diptera: Psychdidae) are insects of the order Diptera. Their morphology is directly related to their lifestyle, the pre-imaginary young stages are terricole while adults are aerial. These insects play an important role in human pathology. Their involvement in the transmission of human and veterinary diseases is now proven (Léger and Depaquit, 2002) [34]. Leishmaniasis are in the first rank of these diseases. In Tunisia, cutaneous leishmaniasis transmission has been increasing since the 1980s, with a significant increase in the incidence of cases and a spread of the geographical distribution. The disease currently represents a major public health problem with a productivity gap and an impediment for development, which results in dramatic socioeconomic and psycho-sanitary impacts. The incidence is more than thousands of cases every year in Tunisia. Visceral leishmaniasis had clustered for a long time in the Northern areas of the country before it extended geographically to the Central parts, overlapping the barrier of the Rif and Atlas Mountains (Kilick-kendrik *et al*., 1999; Aoun *et al*., 2008 [1]; Harrath *et al*., 1996; Rioux *et al*., 2001; Mehabresh *et al*., 1996) [39]. This disease spread is associated with a drastic increase of the number of cases (Rioux *et al*., 2001; Aoun *et al*., 2009) [39, 2]. The emergence of the disease is related to the environmental changes that happened in the early 80's. These changes are mainly induced by the huge mobilization of water resources in the semi and upper arid areas for the development of irrigation and agriculture (Rioux *et al*., 2001; Aoun *et al*., 2009; Louati *et al*., 1998) [39] [2].

Sandflies described in Tunisia (Table 1) include 16 species belonging to 2 genus: *Phlebotomus* Rodani, 1843 and *Sergentomyia* Franca & Parrot, 1920 (Croset *et al*., 1978, Léger *et al*., 1983, Dépaquit *et al*., 1998) [15]. The genus *Phlebotomus* is divided into 3 sub genres: the subgenus *Phlebotomus* Rodani, 1843 with just one specie: *Phlebotomus papatasi* Scopoli, 1786*;* the subgenus *Paraphlebotomus* Theodor, 1948 with four species: *Phlebotomus sergenti* Parrot, 1917; *Phlebotomus alexandri* Sinton, 1928 [4]*; Phlebotomus chabaudi* Croset, Abonnec & Rioux, 1970*; Phlebotomus riouxi* Depaquit, 1998 [20] and the sbgenus *Larroussuis* Nitzulescu, 1931 [33] with 6 species: *Phlebotomus ariasi* Tonnoir, 1921*; Phlebotomus chadlii* Rioux, Juminer et Gibily, 1966*; Phlebotomus perfiliewi* Parrot, 1930*; Phlebotomus perniciosus* Newstead, 1911*; Phlebotomus longicupis* Nitzulescu, 1930*; Phlebotomus langeroni* Nitzulescu, 1930. The genera *Sergentomyia* Franca & Parrot, 1920 is divided into 3 subgenus: le sous genre *Sergentomyia* Franca & Parrot, 1920 with 3 species: *Sergentomyia antennata* Newstead, 1912; *Sergentomyia fallax* Parrot, 1920; *Sergentomyia minuta* Alder & Theodor, 1927; the subgenus *Sintonius* Nitzulescu, 1931 [33] with just one specie: *Sergentomyia christophersi* Sinton, 1927 and the subgenus *Grassomyia* Theodor, 1958 with just one specie: *Sergentomyia dreyfussi* Parrot, 1933. *Sergentomyia (Sintonius) clydei* (Sinton, 1928) [4] has just been recently described by Ayari *et al*, 2016.

Phlebotomus papatasi is a ubiquitous species in Tunisia; the species of sub-genus *Paraphlebotomus* are mainly located in southern Tunisia and sub-genus species of sub-genus *Larroussuis* in central and northern Tunisia (Ghrab *et al*, 2006; Tabbabi *et al*, 2011) [23].

2.9 Mosquitoes

Culicidae are of great medical importance, particularly in epidemiology, because some species are vectors of several pathogens causing serious and sometimes fatal infectious diseases including: Malaria, West Nile virus fever, dengue fever, valley fever Rift, yellow fever, lymphatic filariasis. (Shaffiner *et al*., 2001; Becker *et al*., 2010) [6]. There are about 43 species of mosquitoes in Tunisia (unpublished data, Brhunes *et al*., 2000, Tabbabi *et al*, 2015) [44].

The genus *Culex* contains 11 species (Brhunes *et al*., 2000): *Culex. antennatus, Cx. deserticola, Cx. hortensis, Cx. impudicus, Cx. laticinctus, Cx. mimeticus, Cx. perexiguus, Cx. pipiens, Cx. pusillus, Cx. territans, Cx. Theileri.* There are no recent publications about this genus but several authors (unpublished data) confirmed the non-modification of the old data. It should be noted that *Cx. pipiens* is the most dangerous specie and its distributions is ubiquitous in Tunisia. The distribution of other species cannot be reported given the lack of data and the restriction of catch points (Table 1).

The genus *Aedes* (Ochlerotatus) contains 14 species (Brhunes *et al*., 2000): *O. albineus, O. berlandi, O. caspius, O. detritus, O. dorsalis, O. mariae, O. zammitii, O. pulcritarsis, Ae. echinus, Ae. geniculatus, Ae. vexans, Ae. coluzzi, Ae. Vittatus, Ae aegypti*. There are no recent publications about this genus but several unpublished data confirmed the non-modification of the old data with the exception of *Ae. aegypti* suggested no longer exists in Tunisia. It should be noted that *Ae. aegypti* is the most dangerous specie and its distributions was/is ubiquitous in Tunisia. The distribution of other species cannot be reported given the lack of data and the restriction of catch points. Ochlerotatus caspius and Ochlerotatus detritus are mainly anthropophilic species.

The genus *Culiseta* contains 5 species (Brhunes *et al*. 2000): *Cs.annulata, Cs. fumipennis, Cs. longiareolata, Cs. morsitans, Cs. subochrea*. The genus Uranotaenia contains just one species: *U. unguiculata*.

The genus *Anopheles* contains 12 species: *An. algeriensis, An. cinereus, An. claviger, An. dthali, An. labranchiae, An. marteri, An. multicolor, An. petragnanii, An. plumbeus, An. sergentii, An. superpectus, An. zieman.* Only four species of *Anopheles* were found by Tabbabi *et al*. (2015) [44] despite the sampling effort and the appropriate season of the captures corresponding to the Anopheles activity period in Tunisia*: A. labranchiae, A. multicolor, A. sergentii*, and *A. algeriensis*. During the malaria eradication campaign between 1968 and 1974, 12 species were identified by Brhunes *et al*. (1999). Other investigation reported six species including *A. cinereus* and *A. claviger* (Bouchité *et al*, 1991). *An. labranchiae* (proven vectors) was the predominant species in northern Tunisia, whereas *An. sergentii* and *An. multicolor* (proven and potentially vectors) were prevalent in southern Tunisia. The other species are ubiquitous in Tunisia.

3. Priority recommendations to prepare the country for future public health challenges

3.1 Understanding what a vector is

With regard to the number of arthropod species, the vectors of pathogens constitute only a tiny minority. Studies on systematics, biology and vector-pathogen interactions using morphological, morphometric, biological, behavioral, genetic and genomic data should continue, particularly within species complexes. The vector-parasite interactions, which remain an immense black box, must be particularly investigated.

3.2 Evaluate and predict vector transmission risks

Global changes modify or alter the density and distribution of vectors, their vectorial capacity and their contact with parasites and hosts. These changes may increase or decrease the incidence of a vector-borne disease. The first step is to undertake substantive work on risk indicators. This research must then materialize through the development of risk assessment tools based on validated statistical and theoretical models. A particular effort should be made on transmission models involving a zoonotic reservoir, more complex than in the case of a single host involved.

3.3 Improve current control methods and develop new approaches

Biocide control must be more specific, less polluting and more effective. Research involving entomologists and specialists in the human and social sciences will need to be intensified in order to maximize the acceptability of the methods proposed and the participation of the communities. As regards biological control, although it has proved disappointing in the majority of cases, further research (other bacteria, viruses, fungi, parasites, predators) is needed. As for genetic control, it opens up promising avenues for control. Tunisian research teams must commit themselves in this way through international collaborations.

3.4 Coordinating multidisciplinary research efforts

Vectors do not know borders (Figure 3). Research must be conducted at African, or Mediterranean, and sometimes worldwide. At the national level, there is currently no real national coordination on vector control. A structure such as the Pasteur Institute in Tunisia could play this role as a federating center for research, expertise and training at the national or even Mediterranean level. A specific call for tender on the theme of vector control in Tunisia could be set up jointly by the Ministries of Research, Health, Agriculture and environment.

4. Need of world action to combat the vectors

The problem of vector-borne diseases concerns everyone, not just the health sector. Achieving the goal of sustainable development to ensure good health and well-being will be based on effective vector control. Several approaches that are implemented by different sectors, such as promoting a healthy environment, will be needed to combat and eliminate vector-borne diseases (Sykes and Makiello, 2016). Involving local authorities and communities in broader intersectoral collaboration will be essential to improve vector control interventions, adapting them to specific scenarios defined by local entomological and epidemiological data. Implementation of sustainable response programs that are robust to technical, operational and financial challenges will require the engagement and collaboration of local communities.

To be effective, strong political commitment and long-term investment are needed. This action does not seek to replace or cancel out existing and effective disease-specific strategies or divert attention away from other essential interventions. Rather, it tends to add to these efforts and to assist countries in developing coherent and coordinated interventions to reduce the burden of disease and the growing threat of vector-borne diseases.

This action provides strategic guidance to assist countries and

development partners to urgently strengthen vector control as a key means of disease prevention and response to outbreaks. To achieve this, vector control programs need to be realigned, building on technical capacity building, strengthening of monitoring and surveillance systems, and improvement of infrastructure. Ultimately, this will help implement a comprehensive approach to vector control that will help achieve national and global disease-specific goals and contribute to the achievement of sustainable development goals.

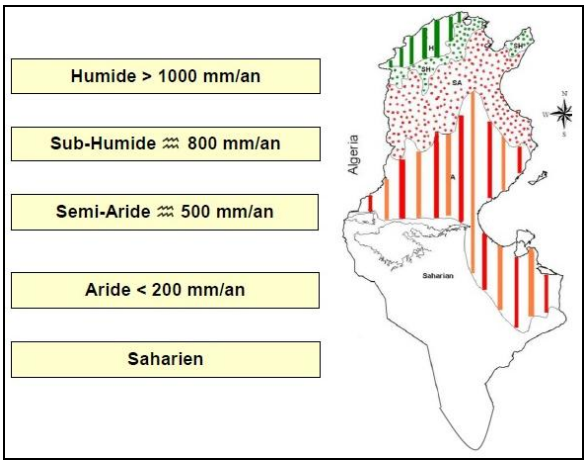

Fig 1: Bioclimatic map of Tunisia (Bouzouaia Noureddine, 2008)

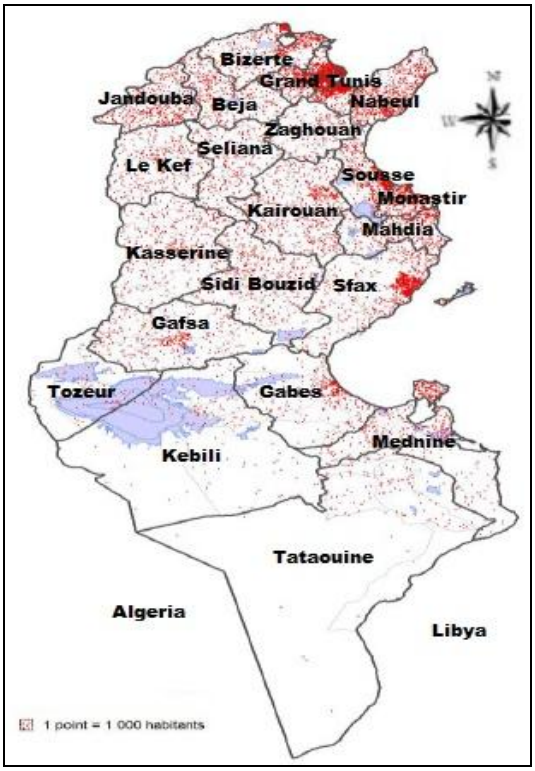

Fig 2: Density of Tunisian populations (Bouzouaia Noureddine, 2008)

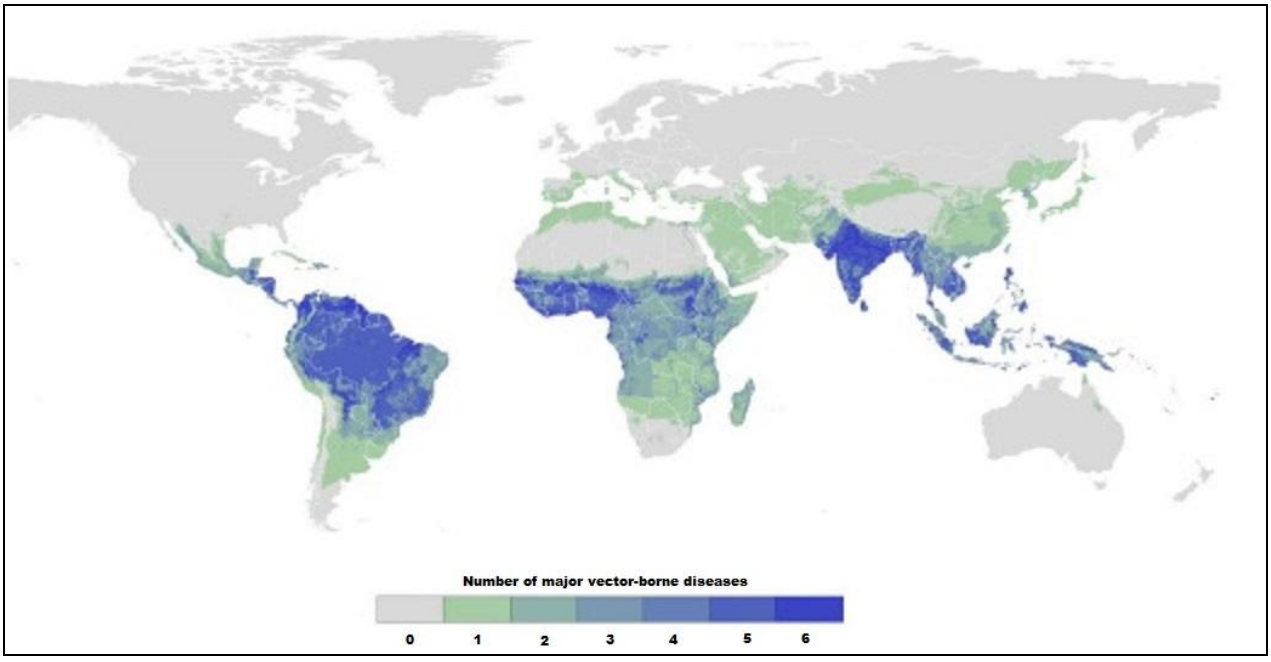

Fig 3: global distribution of the number of major vector-borne disease (Kuehn, 2013)

Table 1: Distribution of medical arthropods in Tunisia (Brhunes et al., 2000; Hamouda and Ben Saleh, 2010; Bouattour et al., 1999; Ben M'rad et al., 2004; Khrouf et al, 2014; Croset et al., 1978; Léger et al., 1983; Dépaquit et al., 1998; Ghrab et al., 2006; Tabbabi et al., 2011)

	Scorpions	Bed bugs	Ticks	Cockroaches	Scabies	Fleas	Lice	Sandflies	Mosquitoes
Bizerte	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Grand Tunis	presence	presence	presence	presence	unknown	presence	absence	presence	presence
Nabeul	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Zaghouan	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Beja	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Jandouba	presence	unknown	presence	presence	unknown	presence	unknown	presence	presence
Le Kef	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Seliana	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Monastir	presence	unknown	presence	presence	unknown	presence	absence	presence	presence

Sousse	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Mahdia	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Kairouan	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Kasserine	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Sidi Bouzid	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Sfax	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Gafsa	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Tozeur	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Gabes	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Medenine	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Kebili	presence	unknown	presence	presence	unknown	presence	absence	presence	presence
Tataouine	presence	unknown	presence	presence	unknown	presence	absence	presence	presence

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