

Ticks of Tunisia, a review

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Abstract

Ticks are ectoparasites of wild and domestic animals and vectors for several pathogens of medical importance and are at the origin of dramatic losses in livestock production. In Tunisia, a total of 18 tick species belonging to 5 genera from the ixodid family were reported: *Hyalomma*, *Ixodes*, *Rhipicephalus*, *Haemaphysalis*, and *Dermacentor*. The soft ticks belonged to the *Ornithodoros* genus with the two species *Ornithodoros normandi* Larrousse and *Ornithodoros erraticus* Lucas were also reported. These tick species were collected from

different bioclimatic zone. Some species have a large geographical distribution and some others their occurrence is limited to some regions or rarely recorded. The most abundant genera are *Hyalomma* and *Rhipicephalus*.

The current review is a synthesis of published data on tick populations in Tunisia, their geographic distribution, preferential hosts, activity dynamics, the pathogens they transmit and tick control programmes.

This study allows to find the gap of knowledge on biology of tick species in Tunisia and to establish a research agenda since many tick species in Tunisia are forgotten or neglected and we don't have information about their vectorial capacity.

Key words: Ticks, Tunisia, distribution, activity dynamics, pathogens, control.

Introduction

Ticks are bloodsucking arthropods of wild and domestic animals and they are responsible for transmitting numerous zoonotic diseases, posing a serious threat to human and animals health and livestock production. A total of 866 tick species have been described throughout the world, of these 18 species were reported in Tunisia colonizing the different bioclimatic zones throughout the country (Bouattour et al., 1999). Then, new species were identified in Tunisia (A Bouattour, Darghouth, & Daoud, 1999; Ali Bouattour et al., 2010; Agustín Estrada-Peña, Nava, & Petney, 2014).

Fourteen species in Tunisia were collected from cattle belonging to the genera of *Hyalomma*, *Rhipicephalus*, *Haemaphysalis*, *Ixodes*, *Dermacentor*. Seven species were collected from sheep identified as *Haemaphysalis punctata*, *Haemaphysalis sulcata*, *Hyalomma excavatum*, *Hyalomma impeltatum*, *Ixodes ricinus*, *Rhipicephalus sanguineus* and *Rhipicephalus turanicus*. Only two species were recorded in goats and identified as *Ixodes ricinus* and *Rhipicephalus turanicus* (A Bouattour et al., 1999).

54 Ticks are involved in the transmission of various pathogens affecting humans and animal health.
55 They are in addition responsible for dramatic losses in livestock production in terms of milk,
56 meat and leather productivity (Chanie, 2013; M. Gharbi et al., 2015; Mohamed Gharbi, Sassi,
57 Dorchies, & Darghouth, 2006).

58 The distribution of ticks is closely related to the presence of hosts, with some species having a
59 huge variability of hosts. Human activities (deforestation, reforestation, urbanization, ...) also
60 affect the distribution of these ectoparasites and thus the pathogens they transmit. In fact, the
61 seasonal transhumance from arid to humid regions in search of grasslands and the migration of
62 birds facilitate the transportation of some ticks from their natural environment to new ones
63 where they have never been reported before and lead to the emergence of pathogens in new
64 regions. For example, in Tunisia, the camel ticks *Hyalomma dromedarii* was found also on
65 cattle in central Tunisia (A Bouattour et al., 1999; Gosrani, 1999).

66 The spatiotemporal fluctuation of ticks depends on environmental factors such as temperature,
67 vegetation and humidity. Climate change disturbs the tick abundance and promotes the
68 emergence of some tick species in new areas (Domşa, Sándor, & Mihalca, 2016). The increase
69 of temperature and the decrease in rainfall allow the spread of thermophilic tick species. Thus,
70 a longitudinal study conducted in 1999 on the ecology and geographic distribution of tick
71 species in Tunisia needs to be updated to account for recent changes in tick distribution. The
72 objective of the present study was to summarize historical and recent data on tick distribution
73 in Tunisia in order to develop an open access database and create maps of tick distribution to
74 inform future efforts for tick-borne disease and tick control.

75

76 **Methods**

77 All published data about ticks in Tunisia were systematically collected searching three
78 databases: PubMed, Web of Science and Google Scholar. Search terms used were ticks Tunisia,

geographic distribution, tick-borne pathogens Tunisia, activity dynamics. The discussion of the results was enhanced by referring to publications from other countries. A total of 192 publications about ticks were selected, 50 of them were about ticks in Tunisia and 30 about ticks in the world served for the discussion. The publications included were related to the ecology of ticks, pathogens transmitted by ticks, impact of climate change in tick abundance and tick-host interaction. All the data were summarized in Table 3 presenting the distribution of tick species and their hosts (the localization of the region in Tunisia were presented in Figure 1) and table 4 is showing all published tick-borne pathogens detected either in ticks or in domestic animals or in vegetation from different regions in Tunisia.

Results

I. Hyalomma genus

The population comprising: *H. scupense*, *H. excavatum*, *H. dromedarii*, *H. marginatum*, *H. aegyptium*, *H. impeltatum*, *H. rufipes*, *H. franchinii*.

1. Hyalomma scupense

a. Hosts and geographic distribution

Hyalomma scupense mainly infests cattle, it is mainly present in Northern regions of Tunisia (A Bouattour et al., 1999; Ende, 1971; Mohamed Gharbi & Aziz Darghouth, 2014; Mohamed Gharbi, Hayouni, Sassi, Dridi, & Darghouth, 2013). (A. Bouattour, 2001) collected this species from the sub-humid (Amdoun region, Beja district), humid (El Jouza, Jendouba district) and semi-arid regions (Sidi Thabet, Ariana district) presenting 83%, 84% and 6.7%, respectively, of the tick population. A few specimens were collected from Sidi Bouzid, Sfax and Gabes in central and southern Tunisia (A. Bouattour, 2001; Gosrani, 1999). It was also recorded in Cap Negro (N=4/25), Amdoun (N=2/25), Sejnane (N=3/25), El Jouf (Zaghouan district) (3/25) (Y. M'ghirbi et al., 2008). This tick species is dominant in Hessiene region (Ariana district) (98.6%;

N=145/147) characterized by semi-arid climate and is an endemic zone for tropical theileriosis (Gharbi *et al.*, 2013a).

b. Life cycle and activity dynamics

Hyalomma scupense is an endophilic and monotropic tick. All stages occur on cattle housed in farms where cracks in walls are common. Adults are active in summer, they were observed between Mai and August with a peak in July (Gharbi *et al.*, 2013a; Gharbi & Aziz Darghouth, 2014) and between June and November (A. Bouattour, Darghouth, & Ben Miled, 1996), while nymphs were recorded between September and November (A. Bouattour *et al.*, 1996) and between October and December (Mohamed Gharbi, Hayouni, *et al.*, 2013). The preferential attachment sites for *Hyalomma scupense* instars were regions with thin skin. In fact, 41 % of adults and 64% of nymphs were collected from posterior udder quarter (Mohamed Gharbi, Hayouni, *et al.*, 2013).

c. Pathological significance

Hyalomma scupense is the main vector of *Theileria annulata* in Tunisia, the agent of tropical theileriosis (TT), and it occurs in almost all North African countries. This disease is considered as the most important tick-borne pathogen in livestock in Tunisia (Darghouth, Bouattour & Kilani, 1999) where its distribution is limited to humid, sub-humid and semi-arid areas. TT occurs in summer with peak in July that coincides with the peak of activity of *H. scupense*. The prevalence in animals ranged between 15.5 and 92.1% using, blood smears and IFAT, respectively.

Table 1: Prevalence of Tropical theileriosis in cattle in Tunisia using different detection methods

Locality (District)	Detection method	Positive/examined (%)	References
Hessiene (Ariana)	IFAT	50/54 (92.1)	(Darghouth <i>et al.</i> , 1996)
Sidi Thabet (Ariana)	Blood smears	46/72 (63.9)	(Darghouth <i>et al.</i> , 2004)
	IFAT	64/72 (88.9)	
Hessiene (Ariana)	IFAT	(92.8)	(Gharbi <i>et al.</i> , 2006)

Bizerte	Blood smears	114/735 (15.5)	(Mohamed Anis Boussaadoun, Mohamed Gharbi, Leila Sayeh & Darghouth, 2015)
Kalaat Al Andalous (Ariana)	PCR	56/66 (61)	(Sallemi, Souhir; Rjeibi, Mohamed R.; Rouatbi, Mariem; Amairia, Safa; Ben Said, Mourad ; Khamassi Khbou, Madiha; Gharbi, 2017)
Bir Elhfay (Sidi Bouzid)	Blood staining PCR	4/140 (2.85) 44/140 (31)	(Elati et al., unpublished data)

Hyalomma scupense was revealed to harbour also *Babesia bovis* (M'ghirbi, Hurtado & Bouattour, 2010).

2. *Hyalomma dromedarii*

a. *Hosts and geographic distribution*

Hyalomma dromedarii infests a variety of hosts, but mainly dromedaries. The other hosts, such as cattle or sheep, can be infested while on common pastures with camels. It was collected from *Camelus dromedarius* from Douz (Kebili district, Southern Tunisia) (Demoncheaux et al., 2012) and from sheep in Tataouine district with an infestation prevalence and intensity of 25.7% and 2.16, respectively (Mohamed R Rjeibi, Darghouth, & Gharbi, 2016). It colonizes the arid and Saharan bioclimatic zone because of its ability to survive under high temperatures.

b. *Life cycle and activity dynamics*

A survey conducted by (Seddik et al., 2016) during one year with one visit per season to 4 districts from Southern Tunisia (Saharan bioclimate zone) showed the occurrence of *Hyalomma dromedarii* during all seasons. From 1200 collected ticks, *Hyalomma dromedarii* was the most prevalent (61%). A maximal infestation of camels by this species was reported in summer (70.7%; N=283/400 ticks) and spring (65%; N=260/400 ticks).

c. Pathological significance

Three females and one male of *H. dromedarii* were collected from an adult castrated male of the species *Camelus dromedaries* in the region of Douz (Southern Tunisia). Two out of four were harbouring DNA of *Rickettsia aeschlimannii* by quantitative PCRs (Demoncheaux *et al.*, 2012). Since the number of tested ticks was very small and no data are available on the prevalence of this pathogen among the dromedary's population in the South, it is very difficult to describe the epidemiology of the infection. Further investigations are needed to identify the prevalence of the infection in dromedaries and other animal species and to understand the involved ticks as vector of *Rickettsia* pathogens.

3. Hyalomma excavatum

a. Hosts and geographic distribution

Hyalomma excavatum parasitizes cattle, sheep, equids and camels, it has been reported across bioclimatic zones in Tunisia. It colonizes mainly arid zones in the central, and Saharan climate in the South with rare population in the humid zone in North of the country. The variety of hosts is related to the large geographic distribution of this species. (Y. M'ghirbi *et al.*, 2008) collected this species from cattle in different regions from Humid, sub humid and semi-arid zones with an average prevalence of 8.8% (N=84/950). From horses, this species was recorded by (Youmna M'ghirbi, Yaïch, Ghorbel, & Bouattour, 2012a) with a prevalence of 7.8% (N=19/243) and later by (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013) from humid and semi-arid bioclimatic zones (16.3%; N=16/120). This species was highly prevalent on sheep from Kebili district (southern Tunisia) (84.3%), which is characterized by a saharan climate. The infestation intensity was estimated to 3.8 Ticks/animals (M. R. Rjeibi *et al.*, 2014). In contrast only few ticks of the *Hyalomma excavatum* species (0.65%) were recorded in goats in Bizerte district belonging to the sub-humid bioclimatic zone (Mourad Ben Said *et al.*, 2015).

b. Life cycle and activity dynamics

Hyalomma excavatum is active throughout the year with low activity during summer. (M. R. Rjeibi et al., 2014) showed the absence of this tick in spring and winter on sheep flocks from the south of Tunisia. (Seddik et al., 2016) found a high activity on camel during autumn season.

c. Pathological significance

This tick species is found on several animal species in Tunisia: cattle, sheep, goats, dromedaries and horses (M'ghirbi et al., 2008b; Ben Said et al., 2013; Rjeibi et al., 2014b, 2015, 2016b; Said et al., 2016a). One study reported 16 specimens of *R. excavatum* collected on horses from a humid region and revealed to harbour *T. equi*. A and D groups (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013).

4. Hyalomma marginatum

a. Hosts and geographic distribution

Hyalomma marginatum infests cattle, small ruminants, equids and camels. It occurs in humid, sub humid and in arid bioclimatic zone. (Y. M'ghirbi et al., 2008) recorded a few number (N=12) from cattle localized in humid and sub-humid sites. This species was also frequent on horses from humid zones 88.8% (N=216/243) (Youmna M'ghirbi et al., 2012a). (Ros-García, M'Ghirbi, Bouattour, & Hurtado, 2011) reported this species in horses from Bizerte and Borj El Amri (subhumid and semi-arid zone, respectively) and another study from humid, sub humid and semi-arid bioclimatic zones found a prevalence of 80.8% (97/120) (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013).

Different species from *Hyalomma* genus were collected from the same biotope or the same hosts. *Hyalomma dromedarii*, *Hyalomma excavatum* and *Hyalomma impeltatum* were collected from dromedaries in Sidi Bouzid (48.4%), Bouficha (9.3%) and Douz (15.3%) (M. Ben Said et

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196 al., 2014). This population was also observed in camels from Kairouan district (Central Tunisia)
197 with a dominance of *H. impeltatum* (53%) followed by *Hyalomma dromedarii* (45%) and
198 *Hyalomma excavatum* (1%) (Mohamed Gharbi, Moussi, et al., 2013). A study conducted in
199 saharan district from south of Tunisia (Tataouine, Mednine, Gabes and Kebili) showed the
200 infestation of camels by four species: *H. dromedarii* (61%), *H. impeltatum* (22%), *H. excavatum*
201 (16%) and *H. marginatum* (1%) among 1200 tick specimens (Seddik et al., 2016).

202 ***b. Life cycle and activity dynamics***

203 *Hyalomma marginatum* was observed on cattle from March to October with peak of infestation
204 during spring (A. Bouattour, 2001). On camels, few number was recorded in spring (8
205 individuals) but it was absent in summer and autumn.

206 ***c. Pathological significance***

207 In Tunisia, *H. marginatum* was investigated mainly in horses and showed to harbour several
208 pathogens such as *Anaplasma phagocytophilum*, *Theileria equi* (A) and (D), *Babesia occultans*
209 and *Babesia caballi*-B. (Ros-García et al., 2011; M'ghirbi et al., 2012b; Ros-García, Amaia;
210 M'ghirbi Youmna; Ana Hurtado, 2013).

211 Three unfed males out of 130 *H. marginatum* collected from horses were positive to *A.*
212 *phagocytophilum* by PCR. Positive serology and PCR detection of DNA is evidence of
213 anaplasmosis circulation in horses, but it's hypothesized that the infection remains silent and
214 animals recover spontaneously (M'ghirbi et al., 2012c). Nevertheless, more attention should be
215 given to the infection, since *A. phagocytophilum* is a zoonotic agent.

216 In the study of (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013), *H. marginatum*
217 collected on healthy horses was highly infected by *Theileria equi* group A in the semi-arid area.
218 Contrarily to *R. bursa*, the role of *H. marginatum* is not demonstrated for *T. equi*, in the
219 Mediterranean area.

220

221 **5. *Hyalomma aegyptium***

222 **a. *Hosts and geographic distribution***

223 It was collected from spur-thighed tortoise (*Testudo graeca*) in Northern Tunisia with a
224 prevalence of 66.2% during May. The preferential attachment sites were the posterior limbs
225 (Mohamed Gharbi et al., 2015).

226 **b. *Life cycle and activity dynamics***

227 The life cycle of *Hyalomma aegyptium* is not studied in Tunisia.

228 **c. *Pathological significance***

229 A total of 602 *H. aegyptium* tick were collected from 201 Tortoises. However, the detection of
230 pathogens was not performed, nor in Tortoises neither in ticks. (Gharbi *et al.*, 2015b).

231

232 **6. *Hyalomma impeltatum***

233 **a. *Hosts and geographic distribution***

234 In Tunisia, adults of this species feed mainly on camels but, they were also collected from cattle.
235 The immature instars infest mainly rodents. The geographic distribution of this species is
236 similar to what has been reported for *Hyalomma dromedarii*. It occurs in arid and Saharan
237 regions characterized by low pluviometry (the mean annual precipitation is 134mm) (Climate-
238 Data.org).

239 **b. *Life cycle and activity dynamics***

240 Its activity seems to be similar to *Hyalomma dromedarii*.

241

242 ***Hyalomma species rarely reported***

243 Other species of *Hyalomma* genus were recorded once or were rarely reported. For example,
244 only two specimens of *Hyalomma franchinii* was recorded in cattle from extreme south of

245 Tunisia (Tataouine district). Its presence was probably related to the introduction of camels
246 from Libya as some herds from the neighbouring countries share the same pasture in some
247 regions in the borders. *Hyalomma marginatum rufipes* was reported in Tunis, Kairouan and
248 Gafsa. These specimens could be imported by migratory birds (A. Bouattour, 2001).

249

250 **II. *Ixodes* genus**

251 **a. *Hosts and geographic distribution***

252 *Ixodes ricinus* infest mainly cattle, and to a lesser extent sheep and goats. It occurs in
253 mountainous areas situated in the Northern humid regions of Tunisia and is characterized by
254 the presence of ferns (*Pteridium aquilinum*) (A. Bouattour, 1987; E Zhioua et al., 1999; H.
255 Younsi, Postic, Baranton, & Bouattour, 2001; Hend Younsi et al., 2005; Dsouli et al., 2006; Y.
256 M'ghirbi et al., 2010; A. Bouattour, 2001). Adults were collected mainly from vegetation
257 (70.8%; N=165/233), cattle (11.7%; N= 393/3367), sheep (6.7%; N=31/462) and goats (7.6%;
258 N=6/79) (A. Bouattour, 2001). Out of 576 ticks collected from cattle localized in humid regions,
259 38 were identified as *I. ricinus* (Y. M'ghirbi et al., 2010).

260

261 **b. *Life cycle and activity dynamics***

262 *Ixodes ricinus* is a three host ticks. The larvae and nymphs were collected from ferns (*Pteridium*
263 *aquilinum*) and infest lizards (*Pseudodromus algirus*) between April and August (A.
264 Bouattour, 2001). Adults were collected mainly from cattle (11.7%, N= 393/3367), sheep
265 (6.7%, N=31/462) and goats (7.6%, N=6/79) during November and from vegetation (70.8%,
266 N=165/233) between September and May (A. Bouattour, 2001).

267 **c. *Pathological significance***

268 In Tunisia, despite the very limited geographic distribution of *I. ricinus*, it was shown to harbour
269 a wide range of pathogens: *Borrelia burgdorferi*, *Anaplasma phagocytophilum*, *Rickettsia*,
270 *Ehrlichia*...

271 ***Borrelia* spp.**

272 In Europe, *I. ricinus* is the main vector of *Borrelia* spp. the agent of Lyme borreliosis
273 (Aeschlimann et al., 1986). Zhioua et al., (1989) was the first to isolate a spirochete from *I.*
274 *ricinus* collected on vegetation in Ain Draham at an altitude of 1040 m. Several studies reported
275 that *I. ricinus* carried *B. burgdorferi* sl. (Zhioua et al., 1999b; Younsi et al., 2001a); *B. lusitanae*
276 (Younsi et al., 2001a; Dsouli et al., 2006); *B. garinii* (Younsi et al., 2001a). *Borrelia lusitanae*
277 is by far the most predominant *Borrelia* species isolated in Tunisia and previous study
278 confirmed that strains have a Portuguese origin (Younsi et al., 2005).

279 ***Anaplasma* spp.**

280 *Anaplasma phagocytophilum* is considered to be the most prevalent tick-borne pathogen in
281 mammals in Europe (Stuen, Granquist & Silaghi, 2013). It's maintained through a cycle
282 gathering the reservoir host and the vector: *I. ricinus*. *Anaplasma phagocytophilum* was
283 investigated in Tunisia in large livestock species (cattle, sheep, goat, dromedaries, horses), but
284 until now, there is no data about its natural host. It was detected for the first time in Tunisia in
285 two *I. ricinus* out of 197 (Sarih et al., 2005) using PCR and sequencing.

286 ***Ehrlichia* spp. and *Rickettsia* spp.**

287 Only *E.*-like DNA was detected in *I. ricinus* in Tunisia in one out of 197 ticks (Sarih et al.,
288 2005). *Rickettsia helvetica* and *R. monacensis* were reported for the first time in Tunisia by Sfar
289 et al., (2008) in *I. ricinus* collected from Northern west Tunisia (Jendouba district). The PCR
290 targeting sequences of gene *gltA* and *rOmpA* (of all *Rickettsia*), revealed that 15/20 and 4/30
291 adult ticks and nymphs, respectively tested positive.

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Piroplasmids

Babesia divergens is the only *Babesia* species transmitted by *Ixodes ricinus* ticks. Darghouth and Bouattour firstly reported *B. divergens* in 1995 from the local cattle breed in Northern Tunisia. The parasite was never detected in *I. ricinus* in Tunisia. However, (M'ghirbi *et al.*, 2010), detected in a mixed infection *Theileria buffeli* and *B. motasi* DNA in one *I. ricinus* collected from the humid region in Tunisia. PCR targeting the hyper-variable region of the 18S rRNA of *Theileria* and *Babesia* coupled to RLB (reverse line blot assay) also led to detect mixed infection of another *I. ricinus* by *T. annulata* and *T. buffeli*. These infections are rather to be attributed to the residual blood meal when *I. ricinus* feed on cattle host than to vector role.

7. *Ixodes inopinatus*

a. Hosts and geographic distribution:

Ixodes inopinatus is recorded in North West of Tunisia by (Agustín Estrada-Peña *et al.*, 2014). It was previously confused with *Ixodes ricinus* in North Africa (Nouredine, Chauvin, & Plantard, 2011).

b. Life cycle and pathological significance

The life cycle and the pathological role of this tick species is still poorly understood and has not yet been studied.

III. *Rhipicephalus* genus

In Tunisia, members of this group are: *Rhipicephalus sanguineus*, *Rhipicephalus (Boophilus) annulatus*, *Rhipicephalus bursa*, *Rhipicephalus turanicus*. These species differed in frequency or abundance, with the variability associated to host species and bioclimatic zone.

316 **8. *R. sanguineus***

317 **a. *Hosts and geographic distribution***

318 *R. sanguineus* is the most abundant species. It occupies all the Tunisian bioclimatic zones from
319 the North to the South. Its distribution is related to dogs (A. Bouattour, 2001; Y. M'Ghirbi et
320 al., 2009; Y. M'ghirbi & Bouattour, 2008) and ruminants living in close proximity to dogs were
321 usually infested. In the district of Sfax (South Est Tunisia), (Khrouf et al., 2014) collected this
322 species mainly from dogs (N=657/663) and only five ticks from sheep.

323 **b. *Life cycle and activity dynamics***

324 All stages of *R. sanguineus* are observed in dogs. (Znazen et al., 2013) collected this species
325 between July and October.

326 **c. *Pathological significance***

327 In Tunisia, *R. sanguineus* was shown to harbour *Babesia canis vogeli* and *Rickettsia* spp.
328 (M'ghirbi & Bouattour, 2008).

329 ***Babesia canis vogeli***

330 M'ghirbi et al. (2008), detected one tick out 160 harbouring *B. canis vogeli* collected from dogs
331 in Somâa region (Northeast Tunisia, Semi-arid). Twelve dogs among 180 (66.66%) analyzed
332 using PCR-RLB tested positive for *B. canis vogeli*. This piroplasm of erythrocytes often leads
333 to moderate or unapparent infection in dogs (Uilenberg et al., 1989) and in some cases to
334 anaemia. (M'ghirbi & Bouattour, 2008), detected one tick out 160 harbouring *B. canis vogeli*
335 collected from dogs in Somâa region (Northeast Tunisia, Semi-arid). Twelve dogs among 180
336 (66.66%) analyzed using PCR-RLB showed positivity to *B. canis vogeli*. This piroplasm of
337 erythrocytes leads often to moderate or unapparent infection in dogs (Uilenberg et al., 1989)
338 and some cases to anaemia.

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***Ehrlichia* spp.**

Ehrlichiosis is of increasing importance and is considered an emergent cause of illness in both humans and animals with a wide range of pathogen species. In Tunisia, the first descriptions were made based on serological tools (Indirect immunofluorescence assay (IIFA). In 1994, Ghorbel published results about 1216 dogs sampled from North to South of Tunisia. The seroprevalence to *E. canis* (possible cross-reaction with *E. chaffeensis*) ranged from 48.6% to 85.4%, in the North-Est and the Centre-Est, respectively. As survey was carried out in winter, it was hypothesized that the centre region was most favourable for *R. sanguineus* survival, while the North and South with very cold winters are not favourable to tick biology. A later survey conducted on healthy dogs (N=153) and their owners (N=195) in Tunis and Bizerte (North Tunisia) showed also high seropositivity in dogs. Indeed, 101/153 dogs' sera reacted positively and simultaneously to *E. canis* and *E. chaffeensis*, while only 3/153 and 1/153 reacted to *E. canis* and *E. chaffeensis*, respectively. Sixty-three per cent of seropositive dogs presented a thrombocytopenia at haematological examination, despite their healthy appearance. Although, the drawbacks of serological tools, these surveys showed that Ehrlichiosis is wide spread among dog population in Tunisia, which is correlated with the large distribution of *R. sanguineus* and that asymptomatic carriage is frequent. Among 195 tested dog owners, 8 were seropositive (4.1%), 6 to *E. canis* and 2 to *E. chaffeensis* and *E. canis* simultaneously (Ghorbel et al., 2000).

***Rickettsia* spp.**

A wide range of *Rickettsia* was detected in *R. sanguineus* in Tunisia. *Rickettsia conorii* subsp *conorii*, *R. massiliae* Bar 29 and *R. conorii* subsp *israelensis* in one, two and six ticks, respectively out of 380 tested (Znazen et al., 2013). The ticks were collected from dogs, sheep and goats living in vicinity of rickettsial infection confirmed patients in Sfax district (Lower arid). Skin and sera from people suspected to have rickettsial infection and suffering from rash was also used in this study. Fifteen among 25 were positive. PCR targeting *OmpA*, *OmpB* and

364 *gltA* genes associated to sequencing were used for genotyping. Multispace typing showed that
365 the same genotype was infecting vectors and humans and underlined the role of *R. sanguineus*
366 as vector of Rickettsia bacteria and Spotted fever group transmission. A similar study showed
367 that 37.3% of *R. sanguineus* were harbouring *Rickettsia* spp. using PCR (23S rRNA).
368 Sequencing performed on selected positive samples allowed the identification of *R. massiliae*
369 Bar 29, *R. conorii* subsp *conorii* and *R. conorii* Israeli spotted fever strain (Khrouf *et al.*, 2014).

370

371 **9. *Rhipicephalus turanicus***

372 **a. Hosts and geographic distribution**

373 *R. turanicus* is widely distributed from humid bioclimatic zone in the North to arid in the centre
374 of the country with important frequency in regions characterized by sub humid and semi-arid
375 climate. (Younna M'ghirbi *et al.*, 2013) showed the abundance of this species on small
376 ruminant (95.5%; N=215/225). Another study carried out by (Mohamed R Rjeibi *et al.*, 2015)
377 showed the high infestation of sheep by this species (45.03%) whereas in other work,
378 (Mohamed Ridha Rjeibi *et al.*, 2014) collected a small number from sheep (N=24) and goats
379 (N=15) in North West and also from centre of Tunisia (Mohamed R Rjeibi *et al.*, 2016).
380 A few population of *R. turanicus* was recorded in one humped camels from central Tunisia
381 (0.5%) that can cohabitated with small ruminants.

382 **b. Life cycle and activity dynamics**

383 *R. turanicus* is reported on ruminants between April and July with peak of infestation during
384 June (A. Bouattour, 2001). It was also recorded between April and June on sheep graze in
385 pasture in different localities (Younna M'ghirbi *et al.*, 2013).

386 **c. Pathological significance**

387 *R. turanicus* feed on cattle and small ruminants and piroplasmid species was frequently detected
388 in this tick species. In Bizerte, 32 *R. turanicus*, collected from cattle, showed DNA traces for

389 *T. buffeli* and *T. annulata* (M'ghirbi et al., 2010). In northern Tunisia, *T. annulata* is frequent
 390 in cattle (Gharbi et Dargouth, 20??) and is very pathogenic piroplasm, causing Tropical
 391 Theileriosis with huge economic losses (Gharbi, 2015). Although, *Hyalomma scupense* is the
 392 natural vector of *T. annulata*, other ticks species, could harbour *T. annulata* DNA after blood
 393 meal of highly parasitized cattle.
 394 In small ruminants, *R. turanicus* was mainly found in sheep in spring. It was shown to harbour
 395 frequently piroplasmids *Theileria* spp. and *Babesia* spp. One hundred Ninty-nine sheep and 64
 396 goats sampled in different bioclimatic stages in Tunisia, carried 215 *R. turanicus*. Sixty-six per
 397 cent of them carried several piroplasmids species, namely: *T. buffeli*, *T. ovis*, *T. equi*, *B. caballi*,
 398 *B. bigemina*, *B. motasi*. This survey allowed first detection of *B. motasi* in Tunisia and *R.*
 399 *turanicus* might be the vector for this parasite (Darghouth, 2004). Mixed infections of ticks
 400 were observed and could be caused by the mixed-infection in hosts (M'ghirbi et al 2013). In
 401 addition to *T. ovis*, *B. ovis* as main piroplasms in small ruminants in Tunisia, other tick-borne
 402 pathogens were reported as *Mycoplasma ovis* (Rjeibi et al. 2014) and *Borrelia burgdorferi* s.l.
 403 (Ben Said et al., 2016). The main role of *R. turanicus* as vector for these pathogens should be
 404 studied.
 405 *Rhipicephalus turanicus* collected from ruminants carry especially piroplasms. Removed *R.*
 406 *turanicus* from cattle, in Bizerte (North), were positive at 17.8% and 8.5% to *T. buffeli* and *T.*
 407 *annulata*, respectively with an overall molecular prevalence about 22.7% (M'ghirbi et al.,
 408 2010).
 409 While *R. turanicus* from small ruminants in 5 localities, were positive to *T. equi*, *T. buffeli*, *T.*
 410 *ovis*, *B. caballi*, *B. bigemina* and *B. motasi* in humid localities, to *T. ovis* in Sub-humid localities
 411 and to mixed infections by *T. buffeli*, *T. equi* and *B. motasi* in Semi-arid localities. In this survey,
 412 sheep expressed highly *Theileria* species infection than goats and some ticks showed positivity,
 413 while their hosts did not (M'ghirbi et al., 2013).

414

415 **10. *Rhipicephalus bursa***

416 **a. *Hosts and geographic distribution***

417 It is the less abundant species in this group. It occurred mainly in humid and sub humid regions
418 but also from semi-arid. A few number (1%) was collected from cattle in North West (Humid
419 regions) of Tunisia by (A. Bouattour, 2001) and in Zaghouan region (arid bioclimatic zone) (Y.
420 M'ghirbi et al., 2010). This species presented only 3% (N=8/243) (Younna M'ghirbi et al.,
421 2012a) and 5.8% (7/120) (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013) of the
422 population infesting horses in humid area. A few number was also recorded in small ruminants
423 from semi-arid zone (4.6%; N=10/215) (Younna M'ghirbi et al., 2013).

424 **b. *Life cycle and activity dynamics***

425 *R. bursa* is monotropic ticks. On cattle, adults stage was observed between May and November
426 with high abundance between May and July.

427 **c. *Pathological significance***

428 *R. bursa* is the principal vector of *Babesia ovis* and *B. bigemina* in Mediterranean basin
429 (Bouattour & Darghouth, 1996). This tick species was demonstrated to harbour *Theileria* spp.
430 and *Babesia* spp. One hundred fifty three *R. bursa* collected from cattle in Oued Abid (Sub-
431 humid) and Zaghouan district (Humid) harboured DNA of *T. annulata* (15/153), *T. buffeli*
432 (12/153), *B. ovis* (13/153), *B. bovis* (1/153) and *B. bigemina* (1/153)(M'ghirbi et al., 2010).
433 Five out of 10 *R. bursa* collected on sheep and goats from El Jouf (semi-arid) showed positivity
434 using molecular method to *B. bigemina*, *T. buffeli* and *T. equi* (M'ghirbi et al., 2013). Among
435 120 ticks removed from horses selected randomly from Humid, Sub-humid and Semi-arid
436 stages, 8 were identified as *R. bursa*. Despite horses has *T. equi* and *B. caballi*, all the examined
437 *R. bursa* were negative for *Theileria/Babesia* catch all probe (Ros-Garcia et al., 2013).

438

439 **11. *Rhipicephalus (Boophilus) annulatus***

440 **a. Host and geographic distribution**

441 *R. annulatus* infest mainly cattle from humid, sub-humid and semi-arid regions
442 (44.5%;N=423/950) (Y. M'ghirbi et al., 2008). This species was the most relevant in the tick
443 population studied in the sub humid region (29.9%;N=172/576) (Y. M'ghirbi et al., 2010).
444 In Bizerte and Beja, (Mourad Ben Said et al., 2015) collected three *Rhipicephalus* species from
445 sheep. The prevalent species was *R. turanicus* (52.77%) followed by *R. sanguineus* (43.96%)
446 and *R. annulatus* (3.26%) and from goats: *R. turanicus* (79.93%) and *R. bursa* (14.47%) with
447 low number of *R. sanguineus* (4.93%).
448 Out of 573 ticks collected from sheep in different bioclimatic zone, only two were identified as
449 *R. camicasi* presented an infestation prevalence of 0.35% (Mohamed R Rjeibi et al., 2015) and
450 one tick collected from sheep in Kebili district (M. R. Rjeibi et al., 2014).
451

452 **b. Life cycle and activity dynamics**

453 *R. annulatus* is active mainly in autumn. In 2001, Bouattour collected this species from cattle
454 in November and december but also in March.

455 **c. Pathological significance**

456 In North Tunisia (Cap Negro (Bizerte district) and Oued Abid (Nabeul district)), collected from
457 cattle, *R. (Boophilus) annulatus* showed to harbour pathogens belonging to *Theileria* and
458 *Babesia* genus. DNA of *T. buffeli* and *T. annulata* were found in 18 and 2 out of 172 ticks,
459 respectively. In addition to DNA of *B. ovis* and *B. bigemina*, for the first time in Tunisia *B.*
460 *motasi* was detected using PCR/RLB in 3 out 179 *R. (Boophilus) annulatus* (M'ghirbi et al.,
461 2010).

462

463 **IV. *Haemaphysalis* genus**

464 In Tunisia, three species belonging to this genus were identified: *Haemaphysalis sulcata*,
465 *Haemaphysalis punctata* and *Haemaphysalis erinacei*.

466 **a. Hosts and geographic distribution**

467 The occurrence of *Haemaphysalis sulcata* and *Haemaphysalis punctata* is limited to the humid
468 and sub-humid regions. *Hae. sulcata* and *Hae. Punctata* share the same habitat with difference
469 of abundance. A little number (0.7%; N=27/4113) of *Hae. Punctata* was collected from cattle
470 in North west of Tunisia (El Jouza, Beja district) and also from sheep and vegetation (1.8%;
471 N=11/614) (A. Bouattour, 2001). A study conducted by (Y. M'ghirbi et al., 2008) showed the
472 presence of this species in Nabeul district (North Est) with a prevalence of 6.6% (N=63/650).
473 *Hae. sulcata* was observed mainly in sheep but also on cattle. Only one tick was sampled from
474 cattle in El Jouf region (Zaghouan district) characterized by semi-arid climate (Y. M'ghirbi et
475 al., 2008) and from Oued Abid localities (Nabeul district, sub humid) (Y. M'ghirbi et al., 2010).
476 Immatures stages of these species were recorded on lizards *Psammodromus algirus* and others
477 reptiles. Only five tick identified as *Haemaphysalis erinacei* were found on hedgehog (A.
478 Bouattour, 2001).

479

480 **b. Life cycle and activity dynamics**

481 *Haemaphysalis sulcata* and *Haemaphysalis punctata* were active between September and
482 February (observed on cattle from October to February). The preferential attachment sites were
483 the neck and the back (A. Bouattour, 2001).

484

485 **c. Pathological significance**

486 Few studies were carried out involving *Haemaphysalis* ticks in Tunisia. Among 38 ticks
487 removed from cattle in Oued Abid (Northeastern Tunisia), 9 and 4 were positive for *T. buffeli*
488 and *T. annulata* respectively (M'ghirbi *et al.*, 2010). Although, *Haemaphysalis* ticks are the
489 main vector of *Babesia motasi* (Uilenberg, 1997), no study were conducted to detect it in
490 Tunisia.

491

492 **V. Dermacentor genus**

493 Among this genus, only *Dermacentor marginatus* was reported in Tunisia.

494 **a. Hosts and geographic distribution**

495 This species is rarely reported. It parasitizes mainly boars and cattle. The few number was
496 recorded in humid regions in Northern west of Tunisia presented 0.8% of the tick population
497 (A. Bouattour, 2001). In the literature, this species was collected from boars in Cap Bon (Nabeul
498 district) characterized by sub humid climate (A. Bouattour, 1982).

499 **b. Life cycle and activity dynamics**

500 The life cycle of this species was not studied in Tunisia due its rarity and its veterinary
501 importance is not addressed.

502 **c. Pathological significance**

503 The vector role of this species was never studied in Tunisia.

504

505 **VI. Ornithodoros genus**

a. Hosts and geographic distribution

There are four soft tick species in Tunisia: *Ornithodoros normandi*, *Carios erraticus*, *Argas reflexus* and *Argas persicus* (Ali Bouattour et al., 2010). These ticks were collected from burrows generally occupied by small mammals such as Jird (*Meriones shawi*) and gerbil (*Gerbillus campestris*). *O. normandi* colonize mainly sub-humid and semi-arid zones. *Carios erraticus* was recorded on sub-humid, arid and Saharan climates. *Argas reflexus* and *Argas persicus* were collected from domestic pigeons (*Columbia livia*) and poultry from sub-humid regions in Northeast of Tunisia.

b. Life cycle and activity dynamics

The life cycles of these species were never studied in Tunisia.

c. Pathological significance

Among this genus, only *O. erraticus* tick species collected from Saharan region in southern Tunisia was shown to be carrier for the DNA of *Borrelia crocidurae* the agent of Tick-borne relapsing fever (Ali Bouattour et al., 2010).

Discussion

To date, a total of 18 tick species had been recorded in all bioclimatic regions from Tunisia (Ali Bouattour et al., 1999). *Ixodes inopinatus* was new captured in Northwest of the country by Agustín Estrada-Peña et al. (2014). The geographic distribution of ticks is determined by several factors. It depends from the ecology of ticks, the host availability, the environmental parameters (altitude, temperature, humidity, rainfall, ...) and the climate conditions (Ali Bouattour et al., 1999; A. Estrada-Peña et al., 2013; Agustín Estrada-Peña & de la Fuente, 2017).

530 Because of a multitude of factors, this current review of tick species is not exhaustive spatial
531 and temporal distribution of ticks is likely to change with time. In fact, there is an active
532 movement of animals not only through Tunisian regions but also with neighbouring countries
533 that increase the possibility of introduction of new species. Also, the migratory birds play an
534 important role in the importation of ticks from Europe as reported previously in Egypt
535 (Hoogstraal et al., 1964). So, others species may be present but have not yet been reported,
536 since few studies on ticks are being carried out and don't cover all bioclimatic zones. This
537 highlights the need to continuously monitor the abundance of ticks and identify new species as
538 these can be vectors for previously absent diseases.

539 The geographic distribution can be impacted by the climate change (Bouattour, 2009; Estrada-
540 Pena, Ayllon, & De La Fuente, 2012; Giorgi, 2006). The increase in temperature and the low
541 precipitation reduce the distribution of ticks adapted to humid climate and extend the
542 distribution of thermophilic ticks (Domşa et al., 2016). Climate change is qualified the "*Driver*
543 *of ticks and tick borne Disease*" (Ogden, Mechai, & Margos, 2013).

544 The variability in tick abundance between different bioclimatic zone is explained by the
545 concentration of their host. In fact, 66 and 44% of cattle and sheep populations, respectively,
546 are concentrated in the north of the country and only 4 and 17%, respectively, are present in the
547 South. Contrarily to goats that 43% of the Tunisian herd are localized in the South (Tunisian
548 Ministry of Agriculture, 2016). The presence of camels in Southern Tunisia (11000 head in
549 Tataouine only) explained the high abundance of *Hyalomma dromedarii* and *Hyalomma*
550 *impeltatum* ticks in these areas.

551 Several studies showed that the host species, the breed, the sex, the age and the immunological
552 status of the infested animal regulate the interaction between the host and the ticks. In the case
553 of *Hyalomma scupense*, calves were 70 times less infested than cows, these animals were less
554 attractive to tick infestation compared to adults that could be explained by the quantity of

attractive volatile gases released by the rumen such as the carboxylic acid and phenol detected by the factory receptors of ticks (Donzé, McMahon, & Guerin, 2004; Stachurski, 1993).

In cattle, different breed showed to be more resistant to tick and tick borne diseases. A study conducted in Gambia, reported the high resistance of N'dama (*Bos taurus*) cattle to tick and tick borne disease comparing to Gobra zebu (*Bos indicus*) cattle implicated a genetic mechanisms (Mattioli & Dempfle, 1995). This resistance related to breed was investigated also in *Bos indicus* and their crosses with *Bos taurus* (Wambura, Gwakisa, Silayo, & Rugaimukamu, 1998). Similar trends were reported in the response of different sheep breed to tick infestation. In South Africa, the indigenous and fat-tailed breed Namaqua Afrikaner showed a high resistance to tick infestation comparing to commercial breed (J. J. E. Cloete, Cloete, Scholtz, & Matthee, 2013; S. W. P. Cloete, Cloete, & Scholtz, 2016). It is also mentioned in Tunisia the low infestation of Barbarine sheep by ticks compared to others local breeds (Elati *et al.*, 2018). Other sheep breed showed a resistance to gastrointestinal infestation (Berton *et al.*, 2017) and mastitis (Banos *et al.*, 2017) and trypanosomosis (Mattioli, Pandey, Murray, & Fitzpatrick, 2000).

The resistance showed by a variety of host against different parasite should be applied as an alternative solution to chemical control against tick infestation, for example, and as a selection index in breeding system (Morris, 2007). As this resistance is genetic, the identification of resistance markers should be considered in genetic improvement programme of animals.

The resistance of tick to acaricides or the pathogens transmitted to treatment is pronounced several times previously as in the case of *Theileria annulata* ((Mhadhbi *et al.*, 2010). The losses due to the impact of parasite in host production have been the objective of several studies. The losses due to the *Theileria annulata* infection in Tunisian cattle (clinical and asymptomatic cases) were estimated at €9388.20 including the losses related to decrease in live weight associated to anaemia, death of the animals in clinical cases and also the cost of treatment (Mohamed Gharbi *et al.*, 2006). Concerning milk production, the daily losses in carrier cows

580 were estimated to 0.77 L/day (M. Gharbi et al., 2015). A similar survey conducted in Algeria
581 showed a decrease in milk production estimated to 2.76 L/day/cow (Ayadi, Gharbi, & Benchikh
582 Elfegoun, 2016).

583 A wide variety of pathogens (*Anaplasma*, *Babesia*, *Borrelia*, *Theileria*...) were detected in
584 ticks. However, the presence of pathogens' DNA does not confirm the vectorial capacity of
585 ticks, neither that vertebrates are competent reservoir for these pathogens (Estrada-Pena et al.,
586 2013). According to Kahl et al., (2002), engorged ticks, as all hematophagous arthropods, when
587 feeding on reservoir host, might imbibe some circulating pathogens with the blood meal. That's
588 why, all findings about the association between pathogens and ticks should be interpreted
589 carefully. Further experiments would be needed to prove vectorial competence in ticks toward
590 determined pathogens.

591 In numerous publications, it has been shown that ticks had mixed infections, such as with
592 *Theileria* and *Babesia* piroplasms. In this context, arises the matter of technique specificity and
593 if molecular tools are enough discriminative. In fact, the design of oligonucleotides probes for
594 RLB should be validated to avoid cross-reactions (Bhoora *et al.*, 2009).

595 As ruminants suffer from several bacterial, viral and parasitic diseases, symptoms of tick-borne
596 diseases could be confounded with others, especially for low pathogenic microbes. Whereas,
597 several other tick-borne pathogens are problematic for both economic and public health level.
598 For example, anaplasmosis is catching more attention at both National and International levels
599 since twenty years ago. Currently it's considered as notified diseases at the World Animal
600 Health Organisation and validated diagnostic tests are recommended for animal trade (OIE
601 World Organization for Animal Health, 2015). In Tunisia, multiple studies have shown that a
602 wide variety of *Anaplasma* species exist in ticks and in domestic animals: *A. bovis*, *A. centrale*,
603 *A. marginale*, *A. ovis*, *A. phagocytophilum*, *A. platys* and related strains to *A. phagocytophilum*
604 and *A. platys* (Said *et al.*, 2014; Belkahia *et al.*, 2015; M'Ghirbi *et al.*, 2016; Ben Said *et al.*,

2017b, 2017a; Ben Said, Belkahia & Messadi, 2018). Although it's prevalence, veterinarians in field are not aware and no technique is standardized for its diagnostic. Moreover, symptoms related to anaplasmosis such as anaemia, jaundice and milk yield decrease are not specific. Our knowledge about ticks, pathogens and hosts need more investigations to better understand this complex relationship. This review also highlighted the role of ticks as disease vectors, which is a threat for human and animal health and thus warrants stronger monitoring and surveillance of ticks and pathogens they may carry. However, interpretation of molecular prevalence should be done with much caution, taking into consideration the whole ecosystem where ticks, pathogen and hosts evolve. Almost all studies are conducted in small-scale area, while the ticks' drivers are larger and more efforts should be deployed to understand the complex tick-borne pathogens transmission.

Regarding the wide distribution of ticks and their role in the transmission of variety of pathogens threatening the livestock productivity, it is important to establish an efficient control programme against ticks and prevent the transmission of pathogens. The control of ticks in Tunisia is applied in several farms but it is not undertaken in others and almost it is without any scientific background. Different control options were recommended consisting of manual tick removal, acaricides application and improvement of cattle enclosures. The choice of control options depends on the size of farms, the density of animals, the presence/behaviour of ticks and the epidemiological situation of the related Tick-borne diseases. These options could be combined together. In the case of endophilic tick species (*Hyalomma scupense*), it is primordial to eliminate the cracks and crevices (place of diapause of ticks) from the farm buildings by plastering inside and outside the walls.

This method is a sustainable control measure that effectively eliminates *H. scupense* and therefore tropical theileriosis in farms. It contributes to a decrease in the prevalence of other livestock diseases (tuberculosis, mastitis, ...). It should be combined with other means of

control. However, the application of this options is limited in practice by the cost of its implementation and its poor acceptability by farmers.

The application of acaricides should be carried out to animals (targeting thin skin regions, posterior udder quarters) and to walls during the summer season. The method of manual tick removal could be applied in small size farms but is not efficient since the ticks can feed on other host species in the farm. This control option can reduce the tick fauna, but it has no effect on tick-borne disease incidence (Mohamed Gharbi & Aziz Darghouth, 2014).

The vaccination is the most efficient control measures against ticks or tick borne pathogens. This option could be applied in regions with high densities of tick fauna. A previous trials with the protein Hd86 have shown a partial effect on nymphs, with no effect on adult ticks (Galaï et al., 2012).

The vaccination against *Theileria annulata* protects animals against disease expression but it does not affect the carrier state and hence the transmission of the challenge parasites to ticks. In this context, several trials were focused on the anti-tick blocking pathogen transmission vaccine in the case of tropical theileriosis and Babesiosis in cattle (Lempereur et al., 2017; Sprong et al., 2018) recommend different strategies to control tick borne disease combining several methods and preventive actions including hygiene measures, anti-tick vaccine seek medical advice in the case of developing symptoms (Lyme borreliosis), avoid tick habitats for forest workers and visitors (vegetation) and application of acaricides. Otherwise, the application of acaricides could be failed due to the development of resistance of ticks to acaricides molecules and could be toxic for humans. To avoid the problem of tick resistance and the toxicity of humans, some authors recommend the use of plant-derived essential oils as an alternative (Torina et al., 2018).

Conclusion

655 Finally, the surveillance of ticks and the pathogens they transmit is with a paramount
656 importance to improve the livestock productivity. This paper is a comprehensive review on
657 ticks and tick-borne pathogens in Tunisia. The information given herein could be helpful for
658 the veterinarian service to make their decision and for the application of an efficient control
659 programme. Further studies should be conducted to better understand the biology of some tick
660 species and their vector role which are neglected. Regarding the movement of animals between
661 different regions in Tunisia and from neighbouring countries, the risk of introduction of new
662 tick species by migratory birds and the climate change, an update of the tick population in
663 Tunisia and their geographic distribution should be carried out.

664

665 **Table 2:** Ticks infesting domestic animals in Tunisia and their biological characteristics

<i>Species</i>	<i>Biology</i>	<i>Hosts of larvae</i>	<i>Hosts of nymphs</i>	<i>Hosts of adults</i>	<i>Geographic distribution</i>
<i>H. excavatum</i>	II	Rodents		Ungulates, carnivorous	From North to South
<i>H. impeltatum</i>	III	Rodents	Rodents	Herbivorous	South
<i>H. scupense</i>	II	Cattle (sheep and equids+++)		Cattle	North, Centre
<i>H. marginatum</i>	II	Birds		Ungulates	North, Centre
<i>H. dromedarii</i>	III	Herbivorous	Herbivorous	Herbivorous	South
	III	Rodents	Rodents		
<i>I. ricinus</i>	III	Reptiles, Birds amphibians, Mammals		Big ungulates	Nord
<i>D. marginatus</i>	III	Rodents	Rodents	PC, Pt. ruminants, Equids	Exceptional
<i>Hae. sulctata</i>	III	Birds, Mammals	Birds, Mammals	Herbivorous, carnivorous (Sheep, in Tunisia)	Nord
<i>Hae. sulcata</i>	III	Lizards	Lizards	Livestock (Sheep, in Tunisia)	Nord
<i>R. sanguineus</i> Wild population	III	Rodents	Rodents	Small ruminants, Dogs	All Tunisia
<i>Domestic population</i>	III	Dogs	Dogs	Dogs	
<i>R. turanicus</i>	III	Rodents	Rodents	Herbivorous, Carnivores	From North to South
<i>R. bursa</i>	II	Ungulates	Ungulates	Ungulates	Nord
<i>B. annulatus</i>	I	Herbivorous	Herbivorous	Herbivorous	Nord

666

667 **Table 3:** Summary of work on tick population in Tunisia, their associated host and their geographic distribution from 1996 to 2017

Genus	Tick species	Percentage (%) [*]	Hosts	Study area		Bioclimatic zone	References
				Districts	Regions		
<i>Hyalomma</i>	<i>Hyalomma scupense</i>	84.3 (4285/5083)	Cattle	Ariana	Sidi Thabet	Semi-arid	(A. Bouattour et al., 1996)
		26.3 (5/19)	Cattle	Monastir	Teboulba	Arid	(Gosrani, 1999)
		23.5 (791/3367)		Beja	Amdoun	Sub humid	(A. Bouattour, 2001)
		16 (4/25)	Cattle	Beja	Cap Negro	Humid	(Y. M'ghirbi et al., 2008)
		8 (2/25)		Beja	Amdoun	Humid	
		12 (3/25)	Cattle	Bizerte	Sejnane	Humid	
		48 (12/25)	Cattle	Bizerte	Maden	Humid	
		12 (3/25)	Cattle	Zaghouan	El Jouf	Arid	(Y. M'ghirbi et al., 2010)
		4 (1/25)	Cattle	Zaghouan	Chwata	Arid	
		2.4 (14/576)	Cattle	Beja	Zaga	Humid	
		98.6 (145/147)	Cattle	Ariana	Sidi Thabet	Semi-arid	(Mohamed Gharbi, Moussi, et al., 2013)
	<i>Hyalomma dromedarii</i>	10.5 (2/19)	Cattle	Monastir	Teboulba	Arid	(Gosrani, 1999)
		0.08 (3/3367)	Cattle	All region**		Arid, saharan	(A. Bouattour, 2001)
		76.5 (153/200)	Camels	All region**		Humid, sub-humid, semi arid, arid	
		4/4	Dromedaries	Kebili	Douz	Arid	(Demoncheaux et al., 2012)
		66.08 (76/115)	Dromedaries	Sidi Bouzid	Sidi Bouzid	Arid	(M. Ben Said et al., 2014)
		45 (733/1630)	Camels	Kairouan	El Alem	Semi-arid	(Mohamed Gharbi, Moussi, et al., 2013)
		7.8 (22/282)	Sheep Goats	Tataouine	Tataouine	Saharan	(Mohamed R Rjeibi et al., 2015)
	<i>Hyalomma dromedarii</i>	28.9 (39/135)	Sheep	Kairouan	Kairouan	Arid	(Mohamed R Rjeibi et al., 2016)
		61 (737/1200)	Camels	Gabes	Hamma	Arid	(Seddik et al., 2016)

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						(A. Bouattour et al., 1996)
<i>Hyalomma excavatum</i>	36.8 (7/19)	Cattle	Gabes	Hamma	Arid	(Gosrani, 1999)
	2.1 (10/462)	Sheep	-	-	Sub humid	(A. Bouattour, 2001)
	1.5 (3/200)	Camels	-	-	Semi-arid arid	
	2/11	Equids	-	-		
	0.09 (3/3058)	Cattle	Beja		Humid	
	4.7 (4/84)	Cattle	Beja	Zaga	Humid	(Y. M'ghirbi et al., 2008)
	1.1 (2/84)	Cattle	Bizerte	Maden	Humid	
	15.4 (13/84)	Cattle	Bizerte	Dar Rmil	Humid	
	11.9 (10/84)	Cattle	Bizerte	Utique	Sub-humid	
	22.6 (19/84)	Cattle	Nabeul	Henchir Chadly	Sub-humid	
	7.1 (6/84)	Cattle	Zaghouan	El Jouf	Arid	
	10.71 (9/84)	Cattle	Zaghouan	Chwata	Arid	
	9.38 (3/32)		Sousse	Bouficha	Semi-arid	(M. Ben Said et al., 2014)
	1 (16/1630)	Camels	Kairouan	El Alem	Semi-arid	(Mohamed Gharbi, Moussi, et al., 2013)
	7.8 (19/243)	Horses	Jendouba Jendouba Jendouba Bizerte	Tabarka Ghardimaou Ain Draham Sejnane	Humid	(Younna M'ghirbi et al., 2012a)
	84.3 118/140)	Sheep	Kebili	Souk Lahad	Saharan	(Mohamed Ridha Rjeibi et al., 2014)
	0.65 (2/304)	Goats	Beja	Amdoun	Humid	(Mourad Ben Said et al., 2015)
	41.8 (118/282)	Sheep and goats	Kebili	Souk Lahad	Saharan	(Mohamed R Rjeibi et al., 2015)

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<i>Hyalomma excavatum</i>	16 (193/1200)	Camels	Kebili	Douz	Saharan	(Seddik et al., 2016)
<i>Hyalomma marginatum</i>	à compléter	Cattle	Ariana	Sidi Thabet	Semi-arid	(A. Bouattour et al., 1996)
	5.2 (1/19)	Cattle	Gabes	Hamma	Arid	(Gosrani, 1999)
	17.6 (592/3367)	Cattle	Bizerte	Utique	Humid	(A. Bouattour, 2001)
		Cattle	Jendouba	Ain Draham	Humid	
		Cattle	Kairouan	-	Arid	
		Cattle	Gabes	-	Arid	
	9/11	Equids	Tataouine	-	Saharan	
	100 (100/100)	Birds				
	4.2 (174/4113)	Cattle	Beja	El Jouza	Humid	
	9 (272/3058)	Cattle	Beja	Amdoun	Humid	
	0.2 (7/3367)	Cattle	Ariana	Kalaat Al-Andalous	Semi-arid	
	16.6 (2/12)	Cattle	Beja	Cap Negro	Humid	(Y. M'ghirbi et al., 2008)
	16.6 (2/12)	Cattle	Beja	Amdoun	Humid	
	16.6 (2/12)	Cattle	Bizerte	Sejnane	Humid	
	25 (3/12)	Cattle	Bizerte	Dar Rmil	Sub-humid	
	25 (3/12)	Cattle	Nabeul	Oued Abid	Sub-humid	
	100 (120/120)	Horse	Bizerte	Sejnane	Humid	(Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013)
	88.8 (216/243)	Horse	Bizerte	Sejnane	Humid	(Youmna M'ghirbi et al., 2012a)
	0.5 (8/1630)	Camels	Kairouan	El Alem	Semi-arid	(Mohamed Gharbi, Moussi, et al., 2013)
	80.8 (97/120)	Horses	-	-	Humid, sub-humid, semi arid	(Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013)
	1 (8/1200)	Camels	Mednine	Oued Fessi	Saharan	(Seddik et al., 2016)

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Rhipicephalus	<i>Hyalomma impeltatum</i>	1 (37/3367)	Cattle	All region**		Arid	(A. Bouattour, 2001)
		9.3 (43/462)	Sheep	All region**		Humid, sub-humid, semi-arid, arid	
		21 (42/200)		Tataouine	-	Saharan	(A. Bouattour, 2001)
		53 (864/1630)	Camels	Kairouan	El Alem	Semi-arid	(Mohamed Gharbi, Moussi, et al., 2013)
		22 (262/1200)	Camels	Tataouine	Beni Mhira	Saharan	(Seddik et al., 2016)
	<i>Hyalomma aegyptium</i>	100 (602/602)	Tortoise	North	-	Humid	(Mohamed Gharbi et al., 2015)
	<i>Hyalomma franchinii</i>	1 (2/200)		Tataouine	-	Saharan	(A. Bouattour, 2001)
	<i>Rhipicephalus sanguineus</i>	21 (4/19)	Cattle	Gabes	Hamma	Arid	(Gosrani, 1999)
		100 (769/769)	Dogs	Beja	Zaga	Humid	(Y. M'ghirbi & Bouattour, 2008)
		0	Dogs	Bizerte	-	Humid	(Y. M'ghirbi et al., 2009)
		78.68 (48/61)	Dogs	Kairouan	-	Arid	
		77.03 (57/74)	Dogs	Nabeul	-	Semi-arid	
		51.72 (30/58)	Dogs	Tunis	-	Semi-arid	
		72.41 (42/52)	Dogs	Beja	Nefza	Humid	
		100 (380/380)	Dogs	Sfax	-	Semi-arid	(Znazen et al., 2013)
		99.03 (657/663)	Dogs	Sfax	Sakiet Ezzit	Arid	(Khrouf et al., 2014)
		0.9 (6/663)	Sheep		Jebeniana Sfax sud Hench Karkennah Mallouleh Sfax ouest Agareb		
		43.96 (404/919)	Sheep	Bizerte	Khetmine	Sub-humid	(Mourad Ben Said et al., 2015)
		4.93 (15/304)	Goats	Beja	Amdoun	Humid	

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	4.6 (13/282)	Sheep and goats	Jendouba	Ain draham	Humid	(Mohamed R Rjeibi et al., 2015)
<i>Rhipicephalus turanicus</i>	9 (306/3367)	Cattle	All region**		Humid, sub-humid, semi-arid, arid	(A. Bouattour, 2001)
<i>Rhipicephalus turanicus</i>	42.85 (198/462)	Sheep	All region**		Humid, sub-humid, semi-arid, arid	(A. Bouattour, 2001)
	92.4 (73/79)	Goats	All region		Humid, sub-humid, semi-arid, arid	
	0.5 (21/4113)	Cattle	Beja	Amdoun	Humid	
	6.8 (15/221)	Sheep	Beja	Amdoun	Humid	
	0.3 (2/614)	Vegetation	Beja	El Jouza	Humid	
	7 (212/3058)	Cattle	Beja	Amdoun	Humid	
	5.55 (32/576)	Cattle	Bizerte	Sejnane	Humid	(Y. M'ghirbi et al., 2010)
	0.5 (8/1630)	Camels	Kairouan	El Alem	Semi-arid	(Gharbi et al., 2013b)
	19.06 (41/215)	Sheep	Jendouba	Tabarka	Humid	(Youmna M'ghirbi et al., 2013)
	4.2 (9/215)	Goats				
	21.4 (46/215)	Sheep	Beja	Amdoun	Humid	
	0	Sheep	Bizerte	Sejnane	Humid	
	8.8 (19/215)	Goats				
	32.5 (70/215)	Sheep	Bizerte	Maaden	Humid	
	0	Goats				
	0	Sheep	Beja	Nefza	Humid	
	3.7 (8/215)	Sheep	Nabeul	Oued El Abid	Sub-humid	
	0	Sheep	Kef	Mellegue	Sub-humid	
	0	Sheep	Zaghouane	El Jouf	Semi-arid	
	10.2 (22/215)	Goats			Semi-arid	

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	61.5 (24/39)	Sheep	Jendouba	Ain Draham	Humid	(Mohamed Ridha Rjeibi et al., 2014)
	38.4 (15/39)	Goats	Jendouba	Ain Draham	Humid	
	52.7 (484/919)	Sheep	Bizerte	Joumine	Humid	(Mourad Ben Said et al., 2015)
	45.03 (127/282)	Sheep	Ariana	-	Semi-arid	(Mohamed R Rjeibi et al., 2015)
<i>Rhipicephalus bursa</i>	2.9 (99/3367)	Cattle	Beja	Amdoun	Humid	(A. Bouattour, 2001)
	26.5 (153/576)	Cattle	Nabeul	Oued Abid	Humid	(Y. M'ghirbi et al., 2010)
	5.8 (7/120)	Horses	Bizerte	Sejnane	Humid	(Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013)
	6/10	Sheep	Zaghouane	El Jouf	Semi-arid	(Youmna M'ghirbi et al., 2013)
	4/10	Goats				(Youmna M'ghirbi et al., 2013)(Youmna M'ghirbi et al., 2013)(Youmna M'ghirbi et al., 2013)(Youmna M'ghirbi et al., 2013)(Youmna M'ghirbi et al., 2013)
	14.47 (44/304)	Goats	Beja	Nefza	Humid	(Mourad Ben Said et al., 2015)
<i>Rhipicephalus annulatus</i>	1.41 (6/423)	Cattle	Beja	Cap Negro	Humid	(Y. M'ghirbi et al., 2008)
	2.83 (12/423)	Cattle	Bizerte	Sejnane		
	8.5 (36/423)	Cattle	Bizerte	Maden	Humid	
	0.47 (2/423)	Cattle	Bizerte	Dar Rmil	Humid	
	47.5 (201/423)	Cattle	Nabeul	Oued Abid	Sub-humid	
	39.2 (166/423)	Cattle	Nabeul	Henchir Chadly	Sub-humid	
	29.8 (172/576)	Cattle	Nabeul	Oued Abid	Sub-humid	(Y. M'ghirbi et al., 2010)
	3.26 (30/919)	Sheep	Bizerte	Joumine	Humid	(Mourad Ben Said et al., 2015)

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		13.8 (465/3367)	Cattle	Bizerte	Sejnane	Humid	(Bouattour, 2001)
	<i>Rhipicephalus camicasi</i>	0.7 (2/282)	Sheep and goats	Kairouan	-	Arid	(Mohamed R Rjeibi et al., 2015)
<i>Ixodes</i>	<i>Ixodes ricinus</i>	100 (72/72)	Vegetation	Beja	Amdoun	Humid	(E Zhioua et al., 1999)
		11.7 (393/3367)	Cattle	Jendouba	Ain Draham	Humid	(Bouattour, 2001)
		6.7 (31/462)	Sheep				
		7.6 (6/79)	Goats				
		70.8 (165/233)	Vegetation				
	<i>Ixodes ricinus</i>	85.5 (3519/4113)	Cattle	Beja	Amdoun	Humid	
		14 (31/221)	Sheep				
		5/5	Goats				
		94 (568/614)	Vegetation				
		24/24	Boars				
		100 (371/371)	Vegetation	Jendouba	Ain Draham	Humid	(H. Younsi et al., 2001)
		45.7 (197/431)	Vegetation	Jendouba	Ain Draham	Humid	(Hend Younsi et al., 2005)
		98.2 (989/1007)	Vegetation	Beja	El Jouza	Humid	(Dsouli et al., 2006)
		4.09 (14/342)	Cattle	Beja	Cap Negro	Humid	(Y. M'ghirbi et al., 2008)
		11.7 (40/342)	Cattle	Bizerte	Sejnane	Humid	
		59.9 (205/342)	Cattle	Bizerte	Maden	Humid	
		5.2 (18/342)	Cattle	Bizerte	Dar Rmil	Humid	
		9.64 (33/342)	Cattle	Nabeul	Oued Abid	Sub-humid	
		4.97 (17/342)	Cattle	Nabeul	Henchir Cahdly	Subhumid	
		2.9 (10/342)	Cattle	Zaghouan	El Jouf	Arid	
		1.46 (5/342)	Cattle	Zaghouan	Chwata	Arid	
		6.6 (38/576)	Cattle	Nabeul	Oued Abid		(Y. M'ghirbi et al., 2010)

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	<i>Ixodes inopinatus</i>	100 (75/75)	Lizard	Jendouba	Ain draham	Humid	(Agustín Estrada-Peña et al., 2014)
<i>Haemaphysalis</i>	<i>Haemaphysalis punctata</i>	2.6 (89/3367)	Cattle	Bizerte	Sejnane	Humid	(Bouattour, 2001)
				Beja	Eljouza	Humid	
				Nabeul	Oued Abid	Sub-humid	
				Nabeul	Haouaria	Sub-humid	
		10.4 (23/221)	Sheep	Beja	Amdoun	Humid	
		1.8 (11/614)	Vegetation	Beja	El Jouza	Humid	
		39.6 (25/63)	Cattle	Nabeul	Oued Abid	Sub-humid	(Y. M'ghirbi et al., 2008)
		6.6 (38/576)	Cattle	Nabeul	Oued Abid	Sub-humid	(Y. M'ghirbi et al., 2010)
	<i>Haemaphysalis sulcata</i>	1 (35/3367)	Cattle	Beja	El Jouza	Humid	(A. Bouattour, 2001)
		1.2 (51/4113)	Cattle	Beja	El Jouza	Humid	
		68.7 (152/221)	Sheep	Beja	El Jouza	Humid	
		3.1 (19/614)	Vegetation	Beja	El Jouza	Humid	
		1/1	Cattle	Zaghouan	El Jouf	Arid	(Y. M'ghirbi et al., 2008)
<i>Dermacentor</i>	<i>Dermacentor marginatus</i>	0.08 (3/3367)	Cattle	Jendouba	Ain Draham	Humid	(A. Bouattour, 2001)
		4.7 (11/233)	Vegetation	Jendouba	Ain Draham	Humid	
<i>Ornithodoros</i>	<i>Ornithodoros erraticus</i>	53.07 (190/358)	Rodents	Zaghouan	Jbel hnoucha	Sub-humid	(Ali Bouattour et al., 2010)
	<i>Ornithodoros normandi</i>	46.9 (168/358)	Rodents	Zaghouan	Jbel hnoucha	Semi-arid	(Ali Bouattour et al., 2010)

Foot notes

(*) Percentage% = (Number of tick species/number of tick collected) *100

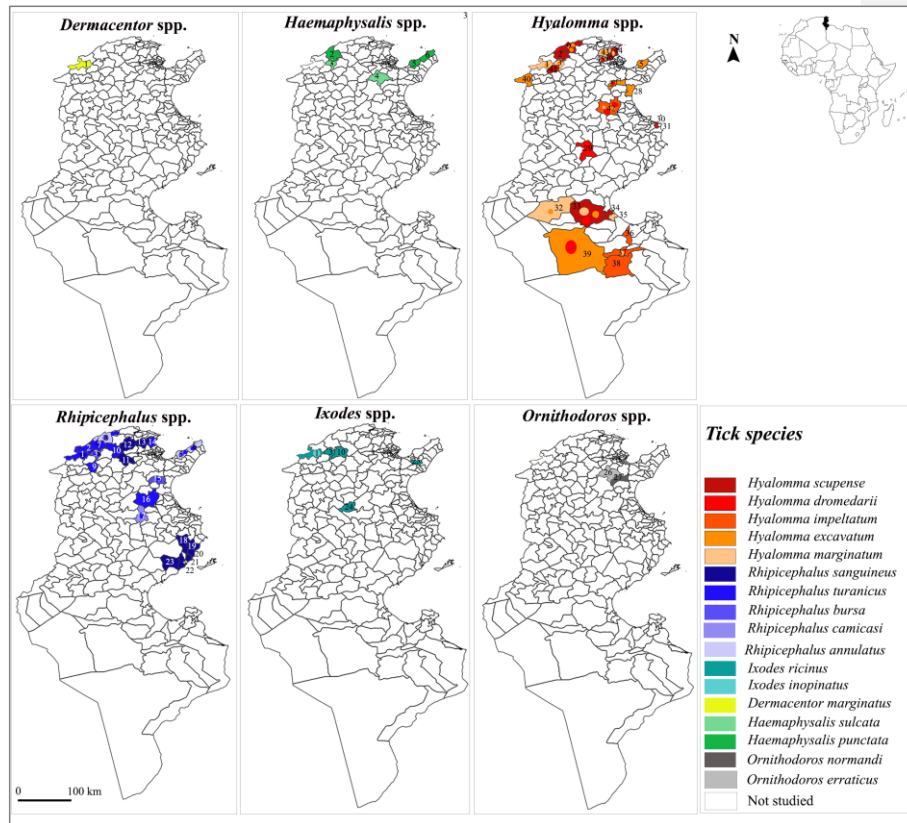


Figure 1: Geographic distribution of tick species in Tunisia (Khawla)

Legend: 1 (Ain Draham); 2 (Tabarka); 3 (Amdoun); 4 (Zaghouan); 5 (Menzel Temime); 6 (Hauouaria); 7 (Nefza); 8 (Sejnane); 9 (Mellegue); 10 (Juomine); 11 (Mjez El Bab); 12 (Khetmine); 13 (Utique); 14 (Kalaat El Andalous); 15 (Bouficha); 16 (Sbikha); 17 (Chebika); 18 (Hench); 19 (Jebeniana); 20 (Sakiet Ezzit); 21 (Sfax ouest); 22 (Sfax Sud); 23 (Agareb); 24 (Kesra); 25 (Oued Abid); 26 (); 27 (Zaghouan); 28 (Bouficha); 29 (Sidi Bouzid); 30 (Teboulba); 31 ([Ksibet El Mediouni](#)); 32 ([Souk Lahad](#)); 33 ([Hamma](#)); 34 ([Gabes West](#)); 35 ([Gabes Sud](#)); 36 ([Mednine Sud](#)); 37 ([Ghomrassen](#)); 38 ([Tataouine Sud](#)); 39 ([Douz](#)); 40 ([Ghardimaou](#)); 41 ([Thibar](#)); 42 ([Sbikha](#)); 43 ([Utique](#)); 44 ([Kalaat El Andalous](#)); 45 ([Tebourba](#)); 46 ([Sidi Thabet](#)).

682 **Table 4:** Prevalence of pathogens detected in ticks and in animals in different locations in Tunisia

Tick species (number collected)	Positive/ Examined ticks	Animal host (N)/ Vegetation	Positive/ Examined animals	Detection method (gene if PCR)	Pathogens	Region (Number on the map)	Reference
<i>Ixodes ricinus</i>	Spirochetes	Vegetation		Culture	Spirochetes	Ain Draham (1)	(Zhioua, Gern & Aeschlimann, 1989)9)
<i>I. ricinus</i>	ND	Cattle (1)	1/1	Isolation (Gerbils) + Inoculation of splenectomised calf+ Giemsa	<i>Babesia divergens</i>	Northwest	(Bouattour & Darghouth, 1996)(A. Bouattour & Darghouth, 1996)
<i>I. ricinus</i>	22/72	Vegetation		DFA	<i>Borrelia burgdorferi</i> s.l.	Amdoun (2)	(E. Zhioua et al., 1999)(Zhioua et al., 1999b)
<i>I. ricinus</i>	61/179	Vegetation		PCR+RFLP	<i>Borrelia burgdorferi</i> s.l.	Ain Draham (1)	(Hend Younsi, Postic, Baranton, & Bouattour, 2001)(Younsi et al., 2001b)
<i>I. ricinus</i>	1/16			PCR+RFLP	<i>B. garinii</i>	Ain Draham (1)	
<i>I. ricinus</i>	15/16			PCR+RFLP	<i>B. lusitanae</i>	Ain Draham (1)	
<i>I. ricinus</i>	19/197	Vegetation		PCR+Seq	<i>Anaplasma phagocytophilum</i>	Ain Draham (1)	(Sarih et al., 2005)(Sarih et al., 2005b)
<i>I. ricinus</i>	2/197				<i>Anaplasma like</i>		
<i>I. ricinus</i>	1/197				<i>Ehrlichia like</i>		
<i>I. ricinus</i>	ND	Vegetation		Culture+ PCR+RFLP+PFGE	<i>B. lusitanae</i>	Ain Draham (1)	(Hend Younsi et al., 2005)(Younsi et al., 2005)
<i>I. ricinus</i>	12/50	Vegetation		PCR (gltA+Omp)	<i>Rickettsia spp.</i>	Jbal Jouza (2)	(Sfar, M'ghirbi, Letaief, et al., 2008)(Sfar et al., 2008b)
<i>I. ricinus</i>	6/7			Seq	<i>R. monacensis</i>		
<i>I. ricinus</i>	1/7			Seq	<i>R. helvetica</i>		

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<i>I. ricinus</i> (1,007)	56/162 (adults) 6/48 (nymphs) 0/32 larvae	Vegetation		DFA	<i>B. lusitanae</i>	Jbal Jouza (2)	(Dsouli et al., 2006) (Dsouli et al., 2006)
		<i>Psammodromus algerius</i> (146)	3/46	Culture +PCR/RFLP	<i>B. lusitanae</i>		
		<i>Psammodromus algerius</i> (146)	14/37	PCR	<i>B. lusitanae</i>		
<i>Rhipicephalus (Boophilus annulatus)</i> (423)	ND	Cattle (278)	104/278	Giemsa	<i>Piroplasms</i>	Cap Negro (3); Amdoun (2); Sajnane (4), Maden (4); Dar Rmil (4) Oued Abid (5); Henchir Chadly (6), El Jouf (7); Chwata (8)	(Y. M'ghirbi et al., 2008) (M'ghirbi et al., 2008b)
<i>I. ricinus</i> (342)	ND		17/86	PCR+RLB	<i>T. annulata</i>		
<i>Hyalomma excavatum</i> (84)	ND		62/86		<i>T. bufelli</i>		
<i>Hy. punctata</i> (63)	ND		7/86		<i>B. bovis</i>		
<i>Hy. detritum</i> (25)	ND		12/49/278		<i>B. bigemina</i> (mixed infections)		
<i>Hy. marginatum</i> (12)	ND						
<i>Hy. sulcata</i> (1)	ND						
<i>Rhipicephalus sanguineus</i> (160)	1/160	Dogs		PCR+RLB	<i>B. canis vogeli</i>	Zaga (9) Somaa (10); Sidi Thabet (11) Bouhajla (12)	(Y. M'ghirbi & Bouattour, 2008) (M'ghirbi & Bouattour, 2008)
<i>R. sanguineus</i> (841)	ND	Dogs (286)	155/286	IFA	<i>Ehrlichia canis</i>	Bizerte	(Y. M'Ghirbi et al., 2009) (M'Ghirbi et al., 2009b)
			9/228	PCR+RLB	<i>E. canis</i>		
			9/228		<i>E. sp.</i>		

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			1/228		<i>A. phagoc</i> + <i>E. canis</i>	
			1/228		<i>A. phagoc</i> + <i>E. sp.</i>	
<i>Rhipicephalus (Boophilus annulatus)</i>	18/172	Cattle (NM)	PCR+RLB	<i>Theileria buffeli</i>	Cap Negro (3) Oued Abid (5)	(Y. M'ghirbi et al., 2010) (M'ghirbi et al., 2010)
	2/172			<i>Theileria annulata</i>		
	0/172			<i>Babesia bovis</i>		
	3/172			<i>B. ovis</i>		
	1/172			<i>B. bigemina</i>		
	4/172			<i>B. motasi</i>		
<i>R. bursa</i>	12/153			<i>T. buffeli</i>	Oued Abid (5) Zaghouan (13)	
	15/153			<i>T. annulata</i>		
	1/153			<i>B. bovis</i>		
	13/153			<i>B. ovis</i>		
	1/153			<i>B. bigemina</i>		
<i>Haemaphysalis punctata</i>	9/38			<i>T. buffeli</i>	Oued abid (5)	
	4/38			<i>T. annulata</i>		
	9/38			<i>Mixed infections</i>		
<i>I. ricinus</i>	1/38			<i>T. buffeli</i>	Oued Abid (5)	
	2/38			<i>Mixed infections</i>		
<i>R. turanicus</i>	5/32			<i>T. buffeli</i>	Bizerte	
	6/32			<i>T. annulata</i>		
	3/32			<i>Mixed infections</i>		
<i>Hy. detritum</i>	2/14			<i>T. annulata</i>	Amdoun (2)	
	1/14			<i>B. bovis</i>		
<i>Hy. marginatum</i>	3/120	Horses	PCR(<i>rRNA18S</i>)+R LB	<i>B. occultans</i>	Sajnane (4), Borj Amri (14); Bizerte	(Ros-García et al., 2011) (Ros-García et al., 2011)
<i>Hy. marginatum</i> (154)	3/130	Horses (60)	nPCR (<i>rRNA16S</i>)	<i>A. phagocytophilum</i>	Bizerte, Jendouba (15) Kef (16)	M'ghirbi et al 2012
	40/60		IFA	<i>A. phagocytophilum</i>		

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<i>Hy. dromedarii</i> (4)	2/4	Dromedaries		qPCR (<i>gltA</i> , <i>Sca1</i>)	<i>R. aeschlimannii</i>	Kébili (17)	(Demoncheaux et al., 2012)(Demoncheaux et al., 2012)
<i>Hy. dromedarii</i>	ND	Dromedaries (226)	9/32	IFA	<i>A. phagocytophilum</i>	Bouficha (18)	(M. Ben Said et al., 2013)(Ben Said et al., 2013)
<i>Hy. excavatum</i>	ND		45/115			Sidi Bouzid (19)	
<i>Hy. impeltatum</i>	ND		12/39			Douz (20)	
		Humans	15/25	PCR (<i>OmpA</i> ; <i>OmpB</i> ; <i>gltA</i>) + Seq	<i>3R. conorii</i> subsp. <i>israelensis</i> +1 <i>R. conorii</i> subsp. <i>conorii</i>	Sfax (21)	(Znazen et al., 2013)(Znazen et al., 2013)
			13/25	MIF	10 <i>R. conorii</i> + 2 <i>R. typhi</i> + 1cross-reaction		
<i>R. sanguineus</i> (380)	6/380 2/380 1/380	Dogs, sheep, goats		PCR (<i>OmpA</i> ; <i>OmpB</i> ; <i>gltA</i>) + Seq	<i>R. conorii</i> subsp. <i>israelensis</i> <i>R. massiliae</i> <i>R. conorii</i> subsp. <i>conorii</i>		
		Sheep (199)	56/199	PCR+RLB	<i>T. ovis</i>	Tabarka (22), Amdoun (2), Sajnane (4), Maaden (4), Nefza (23); Oued Abid (5), Mellegue (25), Touiref (26); El-Jouf (7)	(Younna M'ghirbi et al., 2013)(M'ghirbi et al., 2013)
<i>R. turanicus</i> (215)	66/215	Goats (64)	3/64		<i>T. ovis</i> Catch all <i>Theileria/Babesia</i>		
<i>R. bursa</i> (10)	5/10				Catch all <i>Theileria/Babesia</i>		
Total ticks (225)	9/225 9/225 33/225 20/225				<i>T. equi</i> <i>T. ovis</i> <i>T. bufelli</i> <i>B. motasi</i>		

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<i>Hy. marginatum</i> (97)	3/225 3/225 7/97	Horses		PCR(<i>rRNA18S</i>)+R LB+Seq	<i>B. bigemina</i> <i>B. caballi</i> <i>T. equi</i> (A)	Humid, Sub-humid, Semi-arid	(Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013) (Ros-García, Amaia; M'ghirbi Youmna; Ana Hurtado, 2013)
<i>Hy. excavatum</i> (16)	2/97 1/97 2/13				<i>B. caballi-B</i> <i>T. equi</i> (D) <i>T. equi</i> (A)		
<i>R. bursa</i> (7)	1/13 0/7				<i>T. equi</i> (D)		
		Horses (104)	7/104 2/104 1/104 1/104 2/104		– <i>T. equi</i> (A) <i>T. equi</i> (D) <i>B. caballi-B</i> <i>T. equi</i> (C) Mixed infections		
ND		Horses (343)	14/100 30/122 6/45 0/20 6/56	IFA	<i>A. phagocytophilum</i>	Ariana (27) Manouba (28) Tunis (29) Ben Arous (30) Bizerte (0)	(Mourad Ben Said et al., 2014) (Said et al., 2014)
<i>R. turanicus</i> (39)	ND	Sheep (172)	30/172	nPCR(<i>rRNA18S</i>)+ RFLP	<i>B. ovis</i>	Ain Draham (1)	(Mohamed Ridha Rjeibi et al., 2014) (Rjeibi et al., 2014b)
		Goat (166)	10/172 15/166 0/166		<i>T. ovis</i> <i>T. ovis</i> <i>B. ovis</i>		
		Sheep (172)	7/172	Giemsa stained blood	Piroplasms		

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		Goat (166)	4/166				
<i>Hy. excavatum</i> (118)	ND	Sheep (166)	2/166	Giemsa stained blood	<i>T. lestoquardi</i>	Kébili (17)	(M. R. Rjeibi et al., 2014)(Rjeibi et al., 2014a)
<i>Rhipicephalus</i> spp. (22)	ND		2/166	IFA			
			2/166	PCR+RFLP			
<i>R. sanguineus</i> (663)	74/198	Dogs (16)		PCR(<i>rRNA23S</i>)+R	<i>Rickettsia</i> spp.	Sfax, (21)	(Khrouf et al., 2014)(Khrouf et al., 2014)
		Sheep (12)		LB			
	69/74	Goats (10)		RLB	<i>R. conorii</i>		
	2/5/74			Seq	<i>R. massiliae</i> Bar 29		
<i>Rhipicephalus</i> (turanicus, camicasi, sanguineus)(142)	ND	Sheep (573)	1/172	PCR(<i>rRNA16S</i>)+Seq	<i>Mycoplasma ovis</i>	Jendouba (15)	(Mohamed R. Rjeibi et al., 2015)(Rjeibi et al., 2015)
<i>Hyalomma</i> (<i>dromedarii</i> , <i>excavatum</i>)(140)	ND		35/120			Kairouan (32)	
			0/80			Ariana (27)	
			0/166			Kébili (17)	
			0/35			Tatouine (31)	
		Goat (166)	0/166				
<i>Hy. aegyptium</i> (602)	ND	Tortoise (210)			ND	North	(Mohamed Gharbi et al., 2015)(Gharbi et al., 2015b)
ND		Sheep (260)	20/260	nPCR(<i>rRNA16S</i>)+Seq	<i>A. phagocytophilum</i> related species	Bizerte (0); Béja ()	(Mourad Ben Said et al., 2015)(Said et al., 2015b)
		Goat (303)	144/303				
			244/260	LAMP-PCR(<i>msp4</i>)+Seq	<i>A. ovis</i>		
			198/303				
ND		Cattle (232)	59/232	PCR(<i>msp4</i>)+Seq	<i>A. marginale</i>	Utique (34), Alia (35), Mateur (40)	(Belkahia et al., 2015)(Belkahia et al., 2015)

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			35/232	PCR(<i>rRNA16S</i>)+Se q	<i>A. centrale</i>		
			9/232	PCR(<i>rRNA16S</i>)+Se q	<i>A. bovis</i>		
			26/232		Mixed infections		
		Humans febrile patients (181)	5/181	ELISA	CCHF virus	Mabtouh (36); Sousse (39), Mahdia (38), Sfax (21), Dghoumes (37), Jebli (38)	(Wasfi et al., 2016) (Wasfi et al., 2016) wa
		Humans (slaughterhouse workers (38)	2/38				
		Total humans	0/211	RT rt-PCR			
<i>Hy. scupense</i> + <i>Hy. dromedarii</i> (310)	0/310	Cattle					
ND	ND	Cattle (328)	81/328	PCR duplex(<i>msp2</i> , <i>msp4</i>)+Seq	<i>A. phagocytophilum</i>	Amdoun (2); Sajnane (4), Nefza (23), Dar Rmil (4); Oued Abid (5), Zaghouan (13); Hessiene (41), Utique (34); Kairouan (32)	(Younna M'Ghirbi et al., 2016) (M'Ghirbi et al., 2016)
			0/328 2/328		<i>A. marginale</i> Mixed infections		
<i>Hy. marginatum</i> , <i>Hy. excavatum</i> , <i>Hy. scupense</i>	ND	Cattle (232)	3/232	qPCR(<i>rRNA23S</i>)	<i>Borrelia burgdorferi</i> s.l.	Alia (35), Mateur (40)	(Mourad Ben Said et al., 2016) (Said et al., 2016b)
<i>R. turanicus</i> , <i>R. sanguineus</i> , <i>R. annulatus</i>	ND	Sheep (260)	16/260			Alia (35), Khetmine (42)	
<i>R. turanicus</i> , <i>R. bursa</i> , <i>R. sanguineus</i> , <i>Hy. excavatum</i>	ND	Goats (303)	92/303			Alia (35), Sajenane (4), Joumine (43)	

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<i>Hy. dromedarii</i> , <i>Hy. excavatum</i> , <i>H. impeltatum</i>	ND	Dromedaries (226)	4/226			Bouficha (18), Douz (20)	
ND		Dogs (200)	29/200	nPCR(<i>rRNA18S</i>)+ RFLP+Seq	Catch all (<i>Babesia/Theileria</i>)	North (Humid=>Semi- arid); Centre (Arid)	(Mohamed R. Rjeibi et al., 2016) (Rjeibi et al., 2016a)
			25		<i>B. vogeli</i>		
			4		<i>T. annulata</i>		
<i>Hy. dromedarii</i> (39)	ND	Sheep (270)	8/270	Giemsa staining	Catch all (<i>Babesia/Theileria</i>)		(Mohamed R. Rjeibi et al., 2016) (Rjeibi et al., 2016b)
<i>R. turanicus</i> (96)	ND		34/80	PCR(<i>rRNA18S</i>)+R FLP+Seq	<i>T. ovis</i>	North	
			9/120			Centre	
			1/70			South	
			0/80		<i>B. ovis</i>	North	
			21/120			Centre	
			0/70			South	
			0/270		<i>B. motasi</i>		
		Sheep (355)	25/355	nPCR(<i>rRNA16S</i>)+ Seq	<i>A. phagocytophilum</i> <i>like 1</i>	Bizerte (0); Ariana (27), Tunis (29); Béja (); Nabeul (44)	(Mourad Ben Said, Belkahia, El Mabrouk, Saidani, Ben Hassen, et al., 2017) (Ben Said et al., 2017b)
		Goats (241)	32/241				
		Cattle (367)	7/367				
		Sheep (355)	19/355	nPCR(<i>rRNA16S</i>)+ Seq	<i>A. phagocytophilum</i> <i>like 2</i>		
		Goats (241)	12/241				
		Cattle (367)	2/367				
		Sheep (mean 243)	86/243	PCR(<i>rRNA16S</i>)+Se q	<i>A. ovis</i>	Bizerte (0); Ariana (27), Tunis (29); Béja (); Nabeul (44)	(Belkahia et al., 2017) (Belkahia et al., 2017)

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		17.5/243		<i>A. bovis</i>	
	Goats (mean 178.25)	77.25/178.25		<i>A. ovis</i>	
		19.25/178.25	PCR(<i>msp4</i>)+Seq	<i>A. bovis</i>	
	Sheep (355)	39/355	heminestedPCR(<i>groEL</i>)+RFLP+Seq	<i>A. platys-like</i>	Bizerte (0); Ariana (27), Tunis (29); Béja (); Nabeul (44)
					Mourad Ben Said, Belkhabia, El Mabrouk, Saidani, Alberti, et al., 2017 (Ben Said et al., 2017a)
	Goats (241)	55/241			
	Cattle (367)	13/367			

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685 DFA: direct fluorescence assay
686 ELISA: enzyme-linked immune-sorbent assay
687 IFA: indirect immunofluorescence assay
688 LAMP-PCR: loop-mediated isothermal amplification
689 MIF: micro-fluorescence assay
690 ND: not done
691 NM not mentioned
692 nPCR: nested PCR
693 PCR: polymerase chain reaction
694 PFGE: pulse field gel electrophoresis
695 qPCR: quantitative PCR
696 RFLP: restriction fragment length polymorphism
697 RLB: Reverse line blot hybridization
698 RT-PCR: real time PCR
699 Seq: sequencing
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