First comprehensive survey of Ixodid tick populations on Arabian-Barb horses in Northeastern Algeria: Species inventory and abiotic factors influence

Primer estudio integral de las poblaciones de garrapatas Ixodidae en caballos Árabe-Berbé del noreste de Argelia: Inventario de especies e influencia de factores abióticos

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ABSTRACT

Ticks infestation has been shown to be a real health threat to horses in the Mediterranean basin. To identify the environmental factors underlying this risk, a prospective study was carried out from April to September 2024 on 67 Arabian-Barb horses distributed over six different climatic and geographic sites, ranging from the humid coastal plains of the province El Tarf (4 sites, n = 46, altitude 50-300 m) to the semi-arid interior highlands of the province of Tébessa (2 sites, n = 21, altitude 400-700 m). A total of 825 ticks were manually collected, according to a standardized five-minute inspection protocol, and differentiated microscopically through a detailed morphological analysis of specific characteristics.The results showed that slightly more than the third of the horses were infested (overall: 34.3 %), with an average parasite burden of 36 ticks per animal. More significantly, the distribution of tick species revealed a clear ecological structure (P < 0.001). Species of the genus *Rhipicephalus* dominated largely in humid, low altitude areas, accounting for 86.2 % of the total number of collected ticks. In drier, higher-altitude zones, however, *Hyalomma anatolicum* was the predominant species, representing 54.0 % of all ticks collected. This difference was strongly linked to altitude, as evidenced by statistical correlations: a negative relationship was observed for *R. annulatus* (ρ = -0.79, P = 0.002) and *R. bursa* (ρ = -0.83, P = 0.001), while a positive correlation was found for *H. anatolicum* (ρ = 0.67, P = 0.015). The statistical model integrating altitude and bioclimatic zone alone accounted for 69 % of the observed variance, thereby demonstrating the decisive role of these abiotic factors. However, the sex of the horse (male vs. female) did not show any Signifiant link to infestation risk (p= 0.741).

Key words: Ticks; horses; bioclimate; altitude; Algeria; Mediterranean regions.

RESUMEN

La infestación por garrapatas ha demostrado ser una amenaza real para la salud de los caballos en la cuenca mediterránea. Para identificar los factores ambientales subyacentes a este riesgo, se llevó a cabo un estudio prospectivo de abril a septiembre de 2024 en 67 caballo árabe-bereber distribuidos en seis emplazamientos climáticos y geográficos diferentes, que abarcaban desde las húmedas llanuras costeras de la provincia de El Tarf (4 emplazamientos, n = 46, altitud 50-300 m) hasta las altiplanicies interiores semiáridas de la provincia de Tébessa (2 emplazamientos, n = 21, altitud 400-700 m). Se recolectaron manualmente un total de 825 garrapatas, según un protocolo estandarizado de inspección de cinco minutos, y se diferenciaron microscópicamente mediante un análisis morfológico detallado de características específicas.Los resultados mostraron que algo más de un tercio de los caballos estaban infestados (frecuencia porcentual global: 34.3 %), con una carga parasitaria media de 36 garrapatas por animal. De manera más significativa, la distribución de especies de garrapatas reveló una clara estructura ecológica (P < 0.001). Las especies del género *Rhipicephalus* dominaban ampliamente en las áreas húmedas y de baja altitud, representando el 86.2 % del total de garrapatas recolectadas. Sin embargo, en las zonas más secas y de mayor altitud, *Hyalomma anatolicum* fue la especie predominante, representando el 54,0 % de todas las garrapatas recolectadas. Esta diferencia estuvo fuertemente ligada a la altitud, como lo evidenciaron las correlaciones estadísticas: se observó una relación negativa para *R. annulatus* (ρ = -0.79, P = 0.002) y *R. bursa* (ρ = -0.83, P = 0.001), mientras que se encontró una correlación positiva para *H. anatolicum* (ρ = 0.67, P = 0.015). El modelo estadístico que integraba únicamente la altitud y la zona bioclimática explicó el 69 % de la varianza observada, demostrando así el papel decisivo de estos factores abióticos. Sin embargo, el sexo del caballo (yegua vs. macho) no mostró ninguna relación significativa con el riesgo de infestación (p = 0.741).

Palabras clave: Garrapatas; caballos; bioclima; altitud; Argelia; regiones mediterráneas.

INTRODUCTION

Ticks (Acari: *Ixodida)* is a significant animal health and economic issue for equine breeders around the Mediterranean basin. They impact not only equine welfare but also the financial profitability, primarily through a sensitive decrease in productivity [1]. The harm these ticks cause is due to the inoculation of bioactive saliva loaded with molecules that inhibit coagulation and modulate the immune system, disrupts hemostasis and often causes localized inflammatory reactions on the skin [2]. Furthermore, these molecules play a central role as vectors for various pathogens such as bacteria, viruses, and protozoa, which significantly expand their epidemiological scope [3 , 4].

The Arab-Barb horse (*Equus caballus*) stands out among different equine breeds. Renowned as a genetic symbol of the Maghreb and also valued for its resilience and adaptability, it nevertheless shows a notable susceptibility to tick infestations. Ticks do not only affect the horse's physical capabilities but also reduce its commercial value, thereby compromising the economic stability of equine breeding sectors, whether conventional or undergoing modernization [5].

In the North African context ticks represent a major health concern in equine medicine as they are vectors for pathogens responsible for significant infectious diseases such as piroplasmosis, anaplasmosis, and various theilerioses. The genera *Hyalomma* and *Rhipicephalus* are among the primary vectors implicated in the transmission of these diseases. These conditions have a considerable clinical and economic impact, representing a major obstacle to the sustainability of breeding in the region [6].

Several studies highlight the crucial impact of the environment on the distribution and abundance of ticks. The distribution and population dynamics of ticks are closely linked to environmental factors such as climate, humidity, vegetation, and altitude [7 , 8]. Understanding these biotic interactions is essential. This knowledge is of increasing importance in an era of climate change, which could radically alter the range of these arthropods and, consequently, the geographical spread of the pathogens they transmit [9]. Research conducted in the Maghreb has contributed to a better understanding of these parameters. Indeed, in Tunisia, Gharbi *et al*. [10] demonstrated the influence of seasonal and climatic variations on infestation levels in horses. Similarly, an Algerian study on livestock revealed that the composition of parasitic communities is impacted by environmental gradients [11].

The importance of quantitative studies for understanding tick ecology, demonstrated in North Africa, proves equally crucial in other climatic contexts. Recent work confirms this; In France, under a Mediterranean climate, Nadal and al quantified the precise influence of environmental parameters such as temperature and altitude on parasitic risk [1]. Meanwhile, in ecologically different areas such as Iran, where continental and semi-arid climates predominate, the work of Gholmohammadi *et al.* [12] and al established the seasonal dynamics of infestations in horses.

Recent continental analyses have shown that human-induced land-use changes, combined with climate change, are driving the expansion of ticks and consequently increasing the risk of disease transmission [13 , 14].

However, despite the knowledge already gained, significant gaps persist, particularly concerning the Arab-Barb horse in Algeria. Although this breed constitutes the majority of the national equine herd [15] no study has yet integrated all the abiotic (climate, altitude) and biotic (host, age, sex) factors that could influence tick infestations [16] .This multifactorial approach is nevertheless important for understanding parasite dynamics, as suggested by the results of work on other equine species [17].

The absence of a detailed characterization of tick populations associated with the Arab-Barb horse in the different agro-ecological zones of northeastern Algeria is particularly concerning given that this breed is often raised in resource-limited systems, where it is necessary to implement economical and effective control plans [4] Under such conditions, targeted control methods, based on precise knowledge of local epidemiology, are essential to ensure their sustainability and cost-effectiveness [18].

For an optimal control strategy, it is necessary to identify the tick community; this has proven effective in work concerning livestock in a Mediterranean environment [11]. This work aims to establish the first quantitative inventory of *ixodid* tick species parasitizing the Arabian-Barb horse in northeastern Algeria and to understand how biotic and abiotic factors influence the level of infestation.

MATERIALS AND METHODS

Ethical approval

The study was approved by the Ethics Committee of Department of Veterinary Sciences, Chadli Bendjedid University, El Tarf, Algeria, in accordance with international animal welfare standards (14/2024).

Study period and area

The study was conducted from April to September 2024 across six sites distributed in two Contrasting bioclimatic provinces of northeastern Algeria. The humid region (province of El Tarf, 36°46'N, 8°19'E) is characterized by a humid Mediterranean climate, with an annual rainfall of 600-800 mm and an average temperature of 18.5 °C. Sampling followed a geographical gradient across four localities: the coastal site of Lac des Oiseaux (50-100 m), the intermediate zones of Sidi Kassi (100-150 m), and the inland sectors of Ain El Karma (150-200 m) and El Kala (200-300 m).

The semi-arid region (Province of Tébessa, 35°24'N, 8°07'E) features a semi-arid climate, with an annual rainfall ranging from 300 to 400 mm and a mean temperature of 20.5 °C. Two representative localities were sampled: Ogla Malha (400-550 m), a traditional horse-breeding area in a steppe environment, and Bir El Ater (550-700 m), a border region characterized by resilient horse breeding practices. These two provinces, covering the six study sites, reflect a significant ecological gradient—from humid coastal environments to drier continental interiors—and accurately represent the diverse bioclimatic conditions found across North Africa.

Animals and rearing conditions

The studied ticks were collected from sixty-seven adult Arabian-Barb horses. The latter breed, historically rooted in North African landscapes, is has usually been used for agricultural work, transport, and recreational equestrian activities. Forty-three females and twenty-four males, aged four to fifteen years, distributed across two distinct bioclimatic zones originated from a humid region (n = 46) and a semi-arid region (n = 21). Within an extensive farming system, horses were subjected to similar management practices, which involved the separate handling of males and females.

An exclusive methodological condition was to ensure that no acaricide treatments had been administered to the animals during the six months prior to and throughout the study period, to avoid distorting the observation of natural tick-related epidemiological parameters.

Tick collection and identification

The collection protocol was based on a standardized five-minute monthly examination per horse. Visible ticks were collected and preserved in 70 % ethanol. The taxonomic keys by Estrada-Peña *et al*. [19] and Apanaskevich and Horak [20] were used for morphological identification.

This standard regional approach ensures consistency with established acarological practices.

Epidemiological parameters and statistical analyses

The main indicators of parasitic infestation—namely percentage frequency, mean intensity, and mean abundance—were calculated using the methodology established by Bush *et al*. [21]. For each of these estimates, we determined the 95 % confidence interval to specify their statistical reliability [21].

• percentage frequency = (Number of infested horses/Total number examined) × 100

• Mean Intensity = Total number of ticks/Number of infested horses

• Mean Abundance = Total number of ticks/Total number of horses examined

Statistical analyses were conducted using R software (version 4.3.2), utilizing the lme4, car, and performance packages for modeling and result validation.

Data normality was verified by Shapiro-Wilk test, indicating non-normal distributions (W = 0.82, P < 0.001). Spearman correlations therefore quantified relationships between altitude and species abundance. A generalized linear mixed model (GLMM) analyzed the combined influence of environmental factors with total tick abundance as dependent variable, altitude and bioclimatic zone as fixed effects, and sampling site as random effect. Collinearity was assessed by variance inflation factor. The significance threshold was set at P < 0.05. Data are presented as mean ± standard deviation.

RESULTS AND DISCUSSION

The results of this study reveal a complex epidemiological dynamic, influenced by environmental factors that modulate parasite distribution.

The examination of 67 horses showed that 23 were infested, corresponding to an overall percentage frequency of 34.33 %. Although this figure falls at the lower end of data reported for the Mediterranean basin, it contrasts with higher rates observed in Tunisian equids [10]. Differences in management practices and climate between the two regions could explain this discrepancy. Analysis of parasite loads showed a mean infestation intensity of 35.87 ticks per infested animal and a mean abundance of 12.31 ticks per horse across the entire herd.

This combination of moderate percentage frequency with high individual loads reveals a particular epidemiological profile [22], which suggests that the risk of infestation is not uniformly distributed but rather concentrated within specific ecological foci or on certain individuals.

The analysis of the distribution of the 825 collected ticks confirms the key role of the humidity/aridity gradient. Nearly 70 % of the ticks (67.9 %) came from the humid zone. A Chi-square test confirmed that this difference in total abundance between the zones was highly significant (χ^2 = 105.5, df = 1, P < 0.001).

The detailed breakdown by species, presented in TABLE I, highlights contrasting ecological preferences. The *Rhipicephalus* (*R. annulatus* and *R. bursa*) show a very clear ecological affinity for humidity, with over 80 % of their numbers located in the humid zone. This strong dependence confirms their known physiology [23] and corroborates similar observations on cattle in the region [24].

In contrast, the *Hyalomma* genus shows greater tolerance. Notably, *H. anatolicum* is slightly more abundant in the semi-arid zone (54 % of its numbers), a behavior also observed in Tunisia [25] and likely linked to adaptation to higher temperatures [26]. Finally, the species *D. marginatus* and *I. ricinus*, strictly confined to humid sites, act as true bio-indicators of these forest habitats.

TABLE I ECOLOGICAL DISTRIBUTION OF TICK SPECIES IN HUMID AND SEMI ARID ZONES			
Species	Humid Zone	Semi-Arid Zone	Total
Hyalomma marginatum	208 (65,2 %)	111 (34,8 %)	319
Hyalomma anatolicum	58 (46,0 %)	68 (54,0 %)	126
Hyalomma scupense	47 (51,6 %)	44 (48,4 %)	91
Rhipicephalus annulatus	123 (80,4 %)	30 (19,6 %)	153
Rhipicephalus bursa	65 (84,4 %)	12 (15,6 %)	77
Dermacentor marginatus	20 (100 %)	0 (0 %)	20
Ixodes ricinus	39 (100 %)	0 (0 %)	39
Total	560 (67,9 %)	265 (32,1 %)	825

For each species represent its distribution between zones, calculated as (number of individuals in the zone / total individuals of the species) × 100

The relationship between altitude and the abundance of each species was calculated. The results of Spearman correlations, illustrated in TABLE II, revealed significant relationships. Correlation analyses revealed a strong affinity for low altitudes in the *Rhipicephalus* genera (*R. annulatus*: ρ = -0.79, P = 0.002; *R. bursa*: ρ = -0.83, P = 0.001) and typical forest species (*Ixodes ricinus*: ρ = -0.85, P < 0.001; *Dermacentor marginatus*: ρ = -0.81, P = 0.001).

In contrast, *Hyalomma anatolicum* showed a moderate positive correlation with altitude (ρ = 0.67, P = 0.015). This distribution suggests that the highest slopes in the semi-arid zone provide, along the studied bioclimatic gradient, a more favorable microclimate for this species, thereby demonstrating the complexity of the interactions between ticks and local environmental factors through this particular ecological niche [27].

To synthesize the combined influence of these factors, a GLMM was constructed. Its results, presented in TABLE III, attribute major explanatory power to abiotic factors. The bioclimatic zone and altitude explain approximately 70 % of the observed variance. This result fully validates our environmental approach and makes it a reliable predictive tool for identifying at-risk zones [28].

TABLE II
RELATIONSHIPS BETWEEN ALTITUDE AND ABUNDANCE OF MAIN TICK SPECIES: SPEARMAN'S RANK CORRELATION COEFFICIENTS.

Species	Correlation coefficient (ρ)	P-value	95% Confidence Interval
Rhipicephalus annulatus	-0, 79	0, 002	[-0, 92 to -0, 52]
Rhipicephalus bursa	-0, 83	0, 001	[-0, 94 to -0, 58]
Hyalomma anatolicum	0, 67	0, 015	[0, 38 to 0, 84]
Ixodes ricinus	-0, 85	< 0, 001	[-0, 95 to -0, 62]
Dermacentor marginatus	-0, 81	0, 001	[-0, 93 to -0, 55]

ρ, Spearman's rank correlation coefficient ; CI, Confidence Interval. The Spearman's ρ coefficient was calculated by ranking the altitude and tick abundance values independently and then measuring the strength and direction of the monotonic relationship between these ranks.

TABLE III.
RESULTS OF A GENERALIZED LINEAR MIXED MODEL ANALYZING THE EFFECTS OF ABIOTIC FACTORS ON TOTAL TICK ABUNDANCE

Parameter	Coefficient	Standard Error	z-value	P-value	VIF
Fixed Effects					
Intercept	15,32	3,45	4,44	< 0,001	-
Altitude (m)	-0,018	0,006	-3,00	0,003	1,8
Bioclimatic Zone	8,45	2,87	2,94	0,003	2,1
Random Effect					
Site (Variance)	2,34	1,21	-	-	-
Model Fit					
Marginal R²	0,58	-	-	-	-
Conditional R²	0,69	-	-	-	-

GLMM: Generalized Linear Mixed Model; SE: Standard Error; VIF: Variance Inflation Factor: R², coefficient of determination. The model estimates were calculated using a GLMM with a negative binomial distribution and a log-link function. The coefficients represent the expected change in the log-count of total ticks for a one-unit increase in the predictor, while controlling for random variation between sampling sites.

Contrary to some studies that reported a sex-biased infestation in certain species [29], we did not detect a significant difference in percentage frequency between mares (32.56 %) and males (37.50 %, P = 0.741). It should be noted that these variations can depend on several factors: the tick species involved, the specific pathogen, or the rearing conditions. For example, recent studies conducted on *Dermacentor* ticks in comparable management systems have not shown a significant link between the risk of infestation and the sex of the host animal [30]. This homogeneity could be linked to the extensive rearing conditions of the studied herd, which may standardize exposure to the parasite. Alternatively, it might suggest a homogeneous response of the Arab-Barb breed to infestation, a hypothesis that warrants further study.

The predominant role of these abiotic factors identified in this model is consistent with recent findings from other geographical contexts. Zhang *et al.* [31] recently demonstrated, in ticks of the genus *Hyalomma* in China, that combining climatic variables with occurrence data offers excellent reliability — an approach consistent with the one validated in the present study. This finding is further supported by recent analyses conducted in Xinjiang, where the integration of vector distribution data with climatic and ecological parameters proved equally critical in elucidating the dynamics of tick-borne pathogens [32].

Furthermore, Modeling of *Ixodes ricinus* vector dynamics in Europe has identified land use and precipitation as the main determinants of tick abundance [33]. Lansdell *et al.* [33] demonstrated that humidity-related variables consistently outperform other abiotic parameters in explaining the distribution of this species across European ecosystems. These findings corroborate those of the present study, in which the humidity/aridity gradient also emerges as the major ecological

factor structuring tick communities in the Mediterranean basin. This convergence thus validates the robustness of the environmental approach adopted and its applicability beyond the Algerian context.

Contrary to some older studies that reported a host sexbiased infestation pattern, the present study detected no significant difference in percentage frequency between mares (32.56 %) and males (37.50 %; p = 0.741). This absence of sexrelated bias is consistent with recent molecular observations in *Dermacentor albipictus* [34]. This finding is also in agreement with epidemiological surveys conducted on asymptomatic horses in France [35]. This homogeneity may be related to the extensive rearing conditions of the studied herd, which standardize exposure to the parasite by mitigating potential sexlinked behavioral biases. It might also suggest a homogeneous response of the ArabBarb breed to infestation—a hypothesis that warrants further investigation through controlled studies combining parasite burden measurements with analysis of humoral and cellular immune profiles.

CONCLUSION

This first characterization of tick infestation in the Arab-Barb horse in Algeria reveals an epidemiological profile structured by key environmental factors. This ecological understanding provides a robust foundation for the development of targeted, rational, and economically sustainable management techniques, specifically designed for the region's agricultural systems. It lays the groundwork for integrated and sustainable health management, which is essential for animal welfare and the economic profitability of local agricultural operations.

Conflict of interest

The authors declare no conflict of interest.

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