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Original Article

Influence of transhumance on the spread of *Rhipicephalus microplus* (Canestrini, 1888) in Benin

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ABSTRACT

Objective: *Rhipicephalus microplus* is a very invasive tick whose control is a current challenge. Its speed of propagation is favored by specific risk factors whose knowledge is an essential prerequisite for a good rather design of strategies to put in place for its control. This study consisted of evaluating the influence of transhumance on the spread of this tick in Benin.
Materials and methods: To achieve this objective, two sets of tick sampling were carried out on five animals before and after transhumance in 80 autochthon herds from 8 municipalities in Benin.
Results: The abundance of *R. microplus* varies significantly between breeding type, hosting type, period of ticks collection and between some of their interactions such as: breeding*period, hosting*period and breeding*hosting*period. In addition, the abundance of *R. microplus* according to each of these factors before transhumance differs significantly from the one observed after transhumance; the parasite load of *R. microplus* observed before transhumance is much higher than that observed after transhumance. Transhumance contributes to the spread of *R. microplus* in Benin.
Conclusion: It represents a risk factor on which health risk managers could act in terms of surveillance and control of this cattle tick by carrying out the de-parasitage in the health campaign programs of transhumant animals.

KEYWORDS

Benin; *Rhipicephalus microplus*; Risk Factor; Spread; Transhumance

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INTRODUCTION

Pastoral cattle farming plays a major role in the economy of the countries of tropical Africa (Lesse et al., 2015). In Benin, livestock, especially big cattle, is mainly transhumant with about 2,211,000 head of cattle and 1,678.000 heads of sheep and goats (Faostat, 2014). The feeding of these animals is exclusively based on natural pastures.

In the period of successive pandemics such as Acute Respiratory Syndrome (ARS), bird flu (Morens and Fauci, 2013), it is well known that the transport of healthy or diseased hosts constitutes the elective way of spreading diseases and this on a scale that is not commensurate with the local extension of the initial outbreaks (Barré and Uilenberg, 2010).

Apart from contagiousness, the spread of parasites has these same characteristics. Transport of the infested host can significantly extend the area of occurrence, limited only by availability of hosts and, if necessary, vectors in the area of destination, and by appropriate physical environmental conditions to ensure its survival (Busch et al., 2014). As such, *Rhipicephalus microplus* was probably introduced in Benin between 2000 and 2006 when importing cattle from Brazil or South Africa (Madder et al., 2011). This tick has since invaded vast areas of West Africa. An invasion of this tick can have not only serious economic consequences in the infected areas but also severe losses of production and death resulting from its presence (Walker et al., 2003). A female *R. microplus* requires 0.5 to 3 mL of blood to complete its parasite cycle (Harry et al., 1985).

In case of a massive infestation, animals can lose between 4 and 9.5 Kg in four months and produce 42% less milk worldwide. These losses are 2 to 3 times higher in Australia (Harry et al., 1985). In short, this tick is one of the main threats to health and animal production which dangerously affects the livestock herd (Heekin et al., 2012). It has very short life cycle (3 to 4 weeks) that occurs on a single host unlike other ticks with 3 months as life cycle for *R. appendiculatus* (Walker et al., 2003). Also, its ability to adapt to tropical climates and its resistance to most acaricides currently available on the market are all known factors which contribute to its survival and consequently to its propagation (Bram et al., 2002; Rodriguez-Vivas et al., 2006; Rosario-Cruz et al., 2009). A part from these, does seasonal animal movement not actively contribute to its spread in Benin? The answer to this question will help to better understand the role of transhumance in the distribution of this tick. This can then be taken into account as much as possible in the strategies to be implemented to better control ticks in Benin and in the West African sub region.

MATERIALS AND METHODS

Study area: In order to determine the influence of transhumance on the distribution of *R. microplus* in Benin, a study was conducted on Benin indigenous livestock. Benin is a country located in the inter-tropical zone of Africa between 6°20' and 12°30' north latitude then 1°45' and 2°70' east longitude. It covers an area of 114,763 km². The country is currently divided into 12 administrative departments and 77 administrative municipalities covering three major climatic zones namely: the Guinean or Guinean-Congolese zone with a rainfall ranging between 1,000 and 1,300 mm, the Sudano-Guinean transition zone with a rainfall ranging from 1,100 to 1,200 mm and the Sudanian zone with less than 1,100 mm of rain per year (Gnanglè et al., 2011). The temperature fluctuates between 27 and 31°C and the relative humidity varies between 65% from January to March and 97% in June and July. This annual variation of the seasons allows a nearly year-roung availability of natural and even artificial pasture, thus ensuring a good diet for the animals.

Selection of study sites: The surveyed localities were chosen in collaboration with the Agents of the Regional Action Center for Rural Development (CARDER), the Animal Production Directorate (DPA), and the President of the Departmental Union of Organizations of Professionals and Stock breeders (UDOPER) on basis of transhumance routes and general trend of movement observed on these axes. Three main axes of cross-border transhumance have been selected among five (Djohy, 2010). These axes are as follows:

***AXIS 1**: Tanguieta (entry of Burkina-Faso) - Toucountouna - Natitingou West - Kouande – Pehunco - N'Dali West - Okpara Kika (Parakou) - Kabo -Olodo (Nigeria)*
***AXIS 2**: Mekrou River (transhumant entry) - Banikoara - Along the Alibori River - Kèrou - Tobre (Pehunco) - Sam (Kandi) - Tankongou, Gbagou - Gogounou cattle market - Petit Paris market: - Parakou-Kabo (along the axis 1) - (Nigeria) – Dessari (Kalale) - Sakabansi (Nikki) - (Nigeria) - Biro (Nikki) - Tchikandou (Nigeria)*
***AXIS 3**: Malanville (entrance to Niger) - Engaradebou - Kandi Fô - East Kassakou (Firi village) - East Borodarou (=Abidjan) - Tila - Gogounou center - Livestock market of Petit Paris.*

Thus, considering the great movement of pastoralists and herds on these axes and information from CARDER

agents and the Directorate of Animal Production of Benin (DPA/Benin) on the movement of animals in the country, the municipalities of Banikoara, Natitingou , Pehunco, Bassila, Tchaourou, Save, Zangnanado and Abomey Calavi were selected. It was shown in (**Figure 1**).

Tick collection: Two tick surveys were performed. The first took place from September to October 2016 (before transhumance) and the second from April to May 2017 (after transhumance). For each period, the ticks were taken manually on one of the lateral faces of the body of each of five animals per herd using pointed-nose pliers for 10 minutes: time required to collect the maximum number of ticks at the head, the trunk and the peri-anal area on an animal. The sampling was carried out after the animal was restrained by the herdsmen of each herd. Finally, A GPS was used to collect geographical coordinates of herds.

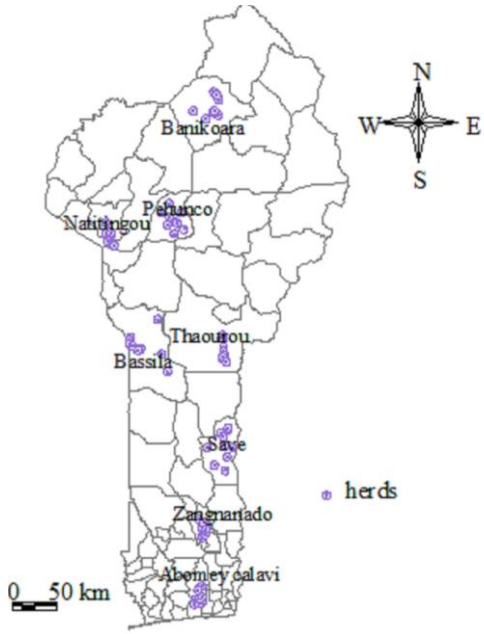

Figure 1. Localization of investigated herds.

Tick conservation: Ticks were kept in vials identified by sampled animal. These flasks contained ethanol at 70°. At the end of each sampling, label carrying necessary information for identification is introduced directly into each flask. The information recorded included the date of collection, the name of the village, the sex and the age of the animal.

Tick identification: Morphological tick identification was performed at the laboratory of Acarology of URBPSA in two phases. The first phase identified ticks to the genus level using a 60X magnification stereoscopic microscope using the identification key developed by Walker et al. (2003). The second phase focused only on the identification of *R. microplus*. For this, a light microscope (Olympus) with 100X magnification was used. The differentiation criteria were based on the number of rows of the dentition, the presence of bristles on the internal protuberance of the first segment of the palpi, the existence of external spur on the coxa II and III, the presence of caudal appendage and the appearance of the ventral plates.

Statistical analysis: Sampling was done on 5 animals in each of 80 autochthon herds targeted in 8 municipalities of Benin. A survey of the herds during the sampling allowed us to distinguish four groups of herds which are: sedentary herds, transhumant herds, herds that host transhumant herds and herds that do not host transhumant herds.

The average numbers of ticks were calculated for the different factors studied, namely the type of breeding, the movement of the herds and their combination. Histograms and box plots were made. Then, the proportion of this tick was calculated by breeding type and movement of herds to assess the importance of its abundance. Means of different groups were compared using then on-parametric Wilcoxon Mann-Whitney test.

Poisson, quasi-Poisson and negative binomial link functions of Generalized Linear Models (GLMs) were tested by considering the main effects of the factors as well as their interactions and then the residual deviance were compared with the residual degree of freedom using the *Chi*-squire test. Then, the model with negative binomial error has been chosen to be adjusted to the observed data. In addition, the best model was selected from the complete model including all factors and covariates considered and their interactions using the "stepAIC" function of the MASS package (Venables and et Ripley, 2002). The significance of the considered factors was tested by making a deviance analysis on the chosen model. All analysis was done with R version 3.2.2 software.

RESULTS

Global abundance of R. microplus in flocks before and after transhumance.

The abundance of *R. microplus* per animal is 53.52 overall before transhumance with a variance of 1367.43, a

Table 1. Proportion of tick numbers of ticks by type of breeding and the movement of herds (Hosting or no hosting other herds transhumant's) before transhumance

Type of breeding	Movement of herds					
	Hosting		No hosting		Total	
	Before	After	Before	After	Before	After
Sedentary	6.92	5.77	22.42	14.01	29.34	19.78
Transhumant	49.55	50.46	21.51	29.76	70.66	80.22
Total	56. 07	56.23	43. 93	43.77	100	100

Table 2: Proportion of tick numbers by type of breeding and the movement of herds (Hosting or no hosting other herd's transhumants) after transhumance.

Type of breeding	Movement of herds		Total
	Hosting	No hosting	
Sedentary	5.77	14.01	19.78
Transhumant	50.46	29.76	80.22
Total	56.23	43.77	100

Table 3. Overall significance of factors and their interaction before transhumance

	Df		Deviance		Resid. Df		Resid. Dev		Pr (>Chi)	
	Before	After	Before	After	Before	After	Before	After	Before	After
NULL					399	399	508.47	508.47		
Breeding	1	1	71.06	71.06	398	398	437.40	437.40	< 0.0001***	< 0.0001***
Hosting	1	1	4.02	4.02	397	397	433.38	433.38	0.0449*	0.0449*
Breeding*Hosting	1	1	15.91	15.91	395	395	390.30	390.30	< 0.0001***	< 0.0001***

*Significance at the 5% level; ***:P<0.001; **:P<0.01; *:P<0.05*

Table 4: Overall significance of factors and their interaction after transhumance

	Df	Deviance	Resid. Df	Resid. Dev	Pr (>Chi)
NULL			399	508.47	
Breeding	1	71.06	398	437.40	<0.0001***
Hosting	1	4.02	397	433.38	0.0449*
Breeding*Hosting	1	15.91	395	390.30	<0.0001***

Significativities at the 5% level; ***: *P*<0.001; **: *P*<0.01; *: *P*<0.05

Table 5. Deviance analysis and significance of factors.

	Df	Deviance	Resid. Df	Resid. Dev	Pr (>Chi)	
NULL			799	8261		
Breeding	1	34,4	798	8226,6	4,48E-09	***
Hosting	1	98,6	797	8128	2,20E-16	***
Period	1	3904,4	794	1449,8	2,20E-16	***
Breeding*Hosting	1	6,7	793	1443,1	0,009856	**
Breeding*Period	1	68,3	789	1359,1	2,20E-16	***
Hosting*Period	1	6	788	1353,1	0,014384	*
Breeding*Hosting*Period	1	17,7	785	957,9	2,60E-05	***

*Significativities at the 5% level; ***:P<0.001; **:P<0.01; *:P<0.05.*
Period = "period of ticks collection, i.e. before transhumance or after transhumance.

Table 6. Comparison of the number of ticks of the two periods for each factor

Factors	Modalities	n	w	Prob.
Breeding	Sedentary	250	180	< 0,0001
	Transhumant	550	4489	< 0,0001
Hosting	Yes	395	1853	< 0,0001
Transhumant	No	405	1475,5	< 0,0001

W=statistics of Wilcoxon Mann-Whitney; n=number of total observations; Prob. = probability of the test significance.

Table 7. Comparison of the number of ticks of the two periods for each combination

Breeding	Hosting	n	w	Prob.
Sedentary	Yes	40	0	< 0,0001
	No	210	78	< 0,0001
Transhumant	Yes	355	1659	< 0,0001
	No	195	663	< 0,0001

W=statistics of Wilcoxon Mann-Whitney; n=number of total observations; Prob. = probability of the test significance.

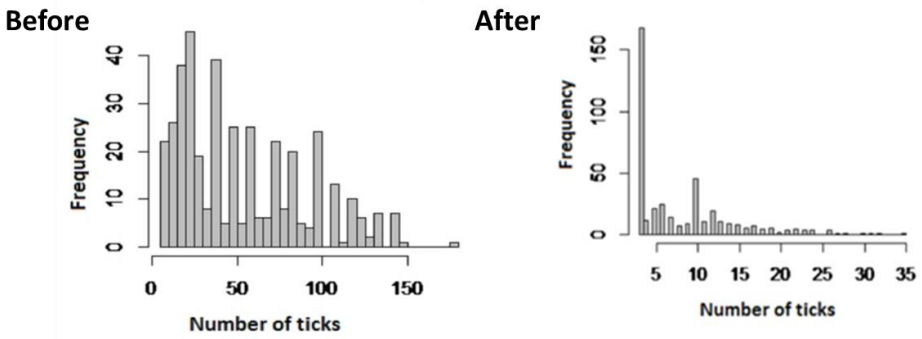

Figure 2. Abundance of *Rhipicephalus microplus* before (a) and after (b) transhumance

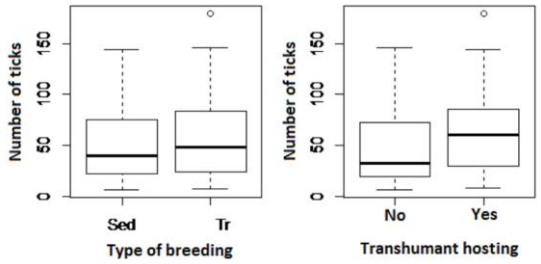

Figure 3. Box plots showing scattering of tick numbers around the average before transhumance. *Sed = Sedentary; Tr= transhumant; no= transhumant no hosting, yes= transhumant hosting.*

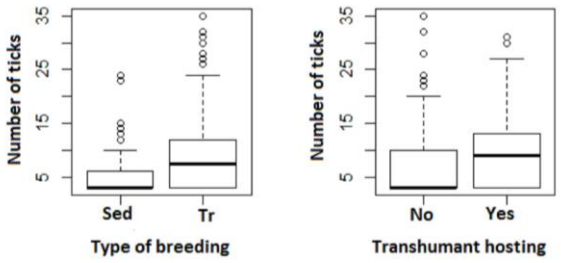

Figure 4. Box plots showing scattering of tick numbers around the mean after transhumance. *Sed = Sedentary; Tr=transhumant; no= transhumant no hosting, yes= transhumant hosting.*

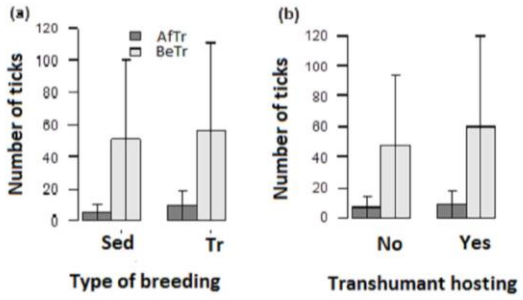

Figure 5. Comparison of the average number of ticks before and after transhumance for each level of factors. *ApTr = after transhumance; AvTr = before transhumance; Sed = Sedentary; Tr= transhumant; no= transhumant no hosting, yes= transhumant hosting.*

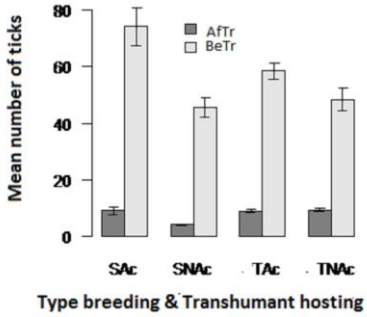

Figure 6. Comparison of the average number of ticks before and after transhumance for each combination of type breeding and hosting transhumant. *SAc = Sedentary hosting transhumant; SNAc = Sedentary no hosting transhumant; TAc = transhumant hosting transhumant; TNAc = transhumant no hosting transhumant.*

variability of more than 25.5 times the average. This dispersion of the data is confirmed by the frequency histogram (**Figure 2a**). After transhumance, this average number is 7.88 with a variance of 38.05, a dispersion of 4.82 times the average (**Figure 2b**).

Average number of R. microplus according to the factors considered

The results obtained before transhumance show that the average number of ticks is higher in transhumant hosting herds than in those who do not, and higher in transhumant herds than sedentary ones (**Figure 3**). The same observation was made after transhumance (**Figure 4**).

Proportion of the parasite load of R. microplus by factors considered.

Considering the total number of *R. microplus* observed in herds before and after transhumance, nearly 50% come from transhumant herds that host other herds in transhumance through their home environment. The proportion of parasite load in livestock herds that do not host transhumance is 22.42% before transhumance

(**Table 1**) and 14% of the total number of *R. microplus* observed in animals sampled after transhumance (**Table 2**).

Modeling the abundance of R. microplus.

The deviance analysis table before and after transhumance (**Table 3-4**) shows that the type of breeding significantly influences the abundance of *R. microplus* observed ($P<0.05$). This abundance is also influenced by the interaction between the type of breeding and the movement of other herds within the sampled regions.

Synthesis the abundance analysis of R. microplus before and after transhumance

According to the deviance analysis table carried out on the "negative binomial" model adjusted to the data compiled over the two periods of ticks collection, it appears that the abundance of ticks observed varies significantly between breeding type, hosting type, period of collection but also between some of their interactions namely: breeding*period, home*period and breeding *home* period (Prob.<0.05) (**Table 5**). In other words, the breeding type and the movement of animals significantly influence the parasite load observed in herds before and after transhumance. In addition, the abundance of *R. microplus* observed for each of these two factors (and their combination) before transhumance differs significantly from that observed after transhumance: Wilcoxon test, Prob.<0.05 (**Table 6-7**). Globally, the abundance of ticks observed before transhumance is much higher than that observed after transhumance for the type of breeding and transhumant hosting and their combination (**Figure 5-6**).

DISCUSSION

Knowledge of the factors that influence tick populations and in particular their distribution is a prerequisite for designing effective control strategies. This study conducted in Benin on transhumance reveals that the parasite load of *R. microplus* observed before transhumance is much higher than that observed after transhumance. There could be a detachment of ticks from their hosts during their travels. This statement justifies the fact that ticks, like all parasites, can easily be disseminated with their hosts (Barré and Uilenberg, 2010). Indeed, *R. microplus*, once attached to its host, can be transported on the latter for a more or less long period. Once this transport is successful, another valuable adaptation for the completion of the cycle is the long survival of the free stadiums, which will be used to wait for a host. During the free-living phase, when the larvae await a favorable host, they can live for up to 5 months after the females detach from the host (Utech et al., 1983; Walker et al., 2003).

The duration of the whole cycle is variable because the longevity of the tick in the non-parasitic phase lasts 2 to 4 months depending on the season (Walker et al., 2007). Thus, the low parasite load observed after transhumance can then be explained by the fact that the period of transhumance coincides with the hottest moments of the year when the activity of ticks is reduced and also the vegetal cover is dry. The animals could not be re-infested before their return. Nevertheless, they infested the environment and once the conditions become favorable, the activity of ticks resumed hence the possible infestation of wildlife: reservoir of many important pathogens (Sarda et al., 2007; Oura et al., 2011; Byaruhanga et al., 2015) and the high parasite burden observed in this study not only at the level of sedentary and transhumant herds that experienced the passage of other transhumant herds in their home environments but also in the period before transhumance.

This study thus reveals that transhumance is a factor favoring the spread of *R. microplus* in Benin. According to (Houndjè et al., 2013) the transhumance of domestic ruminants (in search of pastures and water points) induced transboundary movements of animals that allow the spread of foot-and-mouth disease. Similarly, several studies have shown that animal mobility is a factor favoring the spread of pathogens (Cardoen et al., 2014). However, the biotic and abiotic conditions remain the factors determining the maintenance and abundance of the latter. Indeed, climate and weather changes have a significant impact on the risk of emergence of vector-borne diseases (Léger E et al., 2013; Cardoen et al., 2014).

Cardoen et al. (2014) have shown that heat and humidity condition the multiplication and geographical distribution of certain vectors: hot, dry weather influences tick populations and their geographic distribution. In addition, the duration of the tick cycle depends on several other factors such as the availability, density and nature of the hosts in their biotope (Kimaro et al., 2017). The distribution and abundance of parasites are thus expressed through an interaction that lies between the environment, the climate, the host and the vector. This observation confirms the work of (Lambin et al., 2010). Similarly, several other authors have highlighted the

effect of these parameters in the spread of disease (Estrada-Peña et al., 2013; Abdela Nejash et al., 2016).

CONCLUSION

Transhumance plays a significant role in the spread of *R. microplus* in Benin. Indeed, the high parasite load observed on cattle before their movement is decreasing after displacement. There was a decrease in the number of ticks from their hosts during their travels. Through transhumant herds, we are witnessing the extension of the range of this tick and consequently the likely infestation of wildlife. However, biotic and abiotic conditions have a significant impact in the monitoring and abundance of this tick. A sanitary control based on the external de-parasitation of transhumant herds can contribute to the reduction of the damage caused by the infestation of ticks in general and *R. microplus* in Benin and in the sub-region in particular. It is therefore important to ensure the involvement of tick control in animal disease surveillance programs.

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CONFLICT OF INTEREST

There is no conflict of interest to declare.

AUTHORS' CONTRIBUTION

KJA and YA have participated in developing the protocol, the sample of ticks and in drafting the manuscript. SBA and REY participated in the identification of ticks and the development of the database. PS contributed to the translation of the manuscript. AKIY; MNA and SF supervised the analysis of the statistical results and the correction of the manuscript. All authors have read and approved the content.

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