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Prevalence of hard tick (Acari: Ixodidae) and preliminary observation on Babesia infection on equines in White Nile state, Sudan

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Abstract

Towards understanding Sudan tick-borne diseases, a survey was carried out to investigate the prevalence of hard tick species (Acari: Ixodidae) on equine (donkeys mainly) in the White Nile state, Sudan. It is important to know, as a first step, what types of ticks could affect such animals in such geographical region. A total of 907 ticks collected from 520 donkeys and 4 horses from four cities in White Nile state, during November 2014 to October 2015). The prevalence by location, seasonal and animal breed, sex and age were evaluated. The species composition and prevalence of tick species feeding on donkeys in descending order were as follows: *R. (B.) decoloratus*, *R. evertsi evertsi*, *R. camicasi*, *R. guilhoni*, *A. lepidum*, *Hy excavatum*, *Hy impeltatum*, *Hy. anaticum*, *Hy rufipes*, *Hy dromadarii*. On horses, only *R. guilhoni* was not within the collected species. Additionally, same aforementioned equine species' blood samples were collected and determined for the prevalence of tick-borne diseases. The blood smears (524) were examined using Giemsa-stain method. Out of 520 donkeys, 158 samples (30.2%) were positive for Babesia species however, no positives in the 4 horses' samples. The effect of location and season was observed during this study and discussed accordingly. Such results could enlighten the importance of initiating a national program to precisely investigating such animal diseases, successfully monitor and properly manage such diseases vectors.

Keywords: Ticks, Babesia, equines, White Nile, Sudan

Introduction

In Sudan, to a remarkable extent, a combination of agro-pastoral, mobile and sedentary pastoral production in almost every region and state comprise the main sectors of the Sudanese economy. Sudan possesses a large and diversified animal wealth. The donkey population was estimated at more than eight millions and are divided into two main breeds, Makady which are draught donkeys and Refawy which is a riding donkey [1]. In Sudan, equines are found in all ecological zones and the maximum are at the rural areas where there are no motorized transport and virtually donkeys are the preferred means of pack and riding transport. Hence, facilitating raising drinking water and used for farm services in addition to marketing of agricultural products [2, 3, 4]. However, horses, as in Sudan, have been with humans worldwide and throughout history being served a variety of practical purposes.

Ticks and tick-borne diseases cause dramatically harm to the health of animals that play in maintenance of tick populations and as reservoirs of such tick-borne pathogens [5, 6]. As in Sudan, warm Climatic and socio-economic changes enable ticks to flourish to extend their range of hosts and their spatial and temporal distribution [7]. Additionally, the role played by free-ranging wildlife is also a key point in the occurrence of endemic disease such as ticks and tick-borne diseases of livestock. The complex wildlife-livestock-human in such communal lands increases risk of such disease transmission [8, 9]. In tropical regions, the economically most important hard ticks of livestock belong to the genera *Hyalomma*, *Boophilus*, *Rhipicephalus* and *Amblyomma* [10]. In Africa, while reported that some of ticks constitute threat to human health however, livestock are more affected [9]. In Ethiopia, at the eastern international border of Sudan, several tick species of the genera *Amblyomma*, *Boophilus*, *Haemaphysalis*, *Hyalomma* and *Rhipicephalus* have been reported [11, 12, 13].

In Sudan, *Hyalomma anatolicum* is a vector of *Babesia equi* which causes equine Babesiosis and *Boophilus* species transmit cattle Babesiosis and Anaplasmosis^[14]. Despite these facts, rapid literature scan revealed that in Sudan very few researchers reported the distribution and abundance of tick species on equine in Sudan and there is no systematic research on ectoparasites of equine and just very few sporadic reports^[15, 16, 17, 18, 19, 20, 21, 22]. Furthermore, in Sudan, surveys have suggested the presence of various arboviruses in human populations^[23, 24]. For instance, in Sudan, Crimean-Congo hemorrhagic fever virus (CCHFV) a tick-borne virus has been detected, since 2008, in several sporadic cases and nosocomial outbreaks associated with high case-fatality in the Kordofan region^[25], a region that bordering the White Nile state. Additionally, CCHFV specific antibodies have been detected in animals all of which had been imported to these countries from Sudan. For example, in camels in Egypt, and in sheep and goats in Jeddah, Saudi Arabia^[26, 27]. Furthermore, Alkhurma is a severe and very closely related virus to Kyasanur Forest disease was first reported in Saudi Arabia^[28]. In 2010 the disease was reported in Italian travelers returning from Egypt and tick bite was incriminated as a source of infection while riding on camels. Additionally, the two tick species so far identified as potential vectors of Alkhurma virus^[29] are there in Sudan. Therefore, riding on donkeys and horses could transmit such dangerous viruses when exist. Apparently, the problem is serious word-wide because there is no vaccines for such very dangerous pathogens and it is severe in developing countries where the resources even for the management of ticks are very limited. Moreover, the epidemiological factors determine the occurrence and prevalence of such diseases including animal breed, gender and age in addition to tick species available, its densities and the management measures adopted plus the geographical location and season^[30, 31]. In fact, detailed knowledge of such diseases, the tick population dynamics and exploring the risk factors associated with diseases and ticks' infestation enables to design management strategies.

Apparently, in Sudan, however, there is paucity of information on ticks and tick-borne diseases of donkeys. For instance, rare equine Babesiosis disease was reported however, their vectors are not so far well known. Hence, the objectives of the present study were to determine the ticks prevalence on equine, their geographical distribution in the White Nile state, and the effect of the animal breed, sex and age in addition to determination of *Babesia* in animal blood smears by Giemsa stain as a first step towards a foreseeable future detailed study.

Materials and Methods

Study area

The White Nile passes in the mid of this state. The White Nile state borders by Khartoum state in the north, Gezira state in the east, Kordofan region in the west and South Sudan Republic international border in the south. The ticks collection was performed in four sites: Eldowaim and Elgitaina (eastern bank of the White Nile) and Rabak and Kosti on the western bank of the White Nile.

Study animals

Thirty donkeys were randomly selected from each of the aforementioned four locations, every two months, year-round from November 2014 to October 2015 (6 collections). Cross-sectional study design was implemented to determine the distribution and abundance of males and females tick species

during three seasons: Winter (November to February), summer (March to June) and autumn (July to October).

Ticks collection and identification methods

Ticks were collected from all body of animals using forceps and were preserved with 70% alcohol in universal bottles separately. Date of collections and place of collections were recorded. The taxonomic key of^[15, 32, 33] were used to identify ticks under Stereomicroscope. All data recorded in this study were entered into Microsoft excel and subsequently analyzed using SPSS 16.0 computer program. Descriptive statistics and Chi-square test was used to determine the variation in tick burden between different groups of locations and seasons.

Blood Samples collection and estimation of parasitemias

Blood samples (total 520 donkeys and 4 horses) were collected from four donkeys' markets: Elgitaina and Rabak (Eastern bank of the White Nile) and Eldowaim and Kosti (on the western bank) and animal breed gender and age were recorded. Blood smears were prepared from the donkeys and horses' jugular vein blood and determined for the presence of *Babesia* by Giemsa stain and 1000× magnification was used for identifying blood parasites as described by^[34, 35]. Data collected from this study were compiled in Excel and descriptive statistics using software STATISTIX-8 was used. The 95% confidence intervals and $p < 0.05$ were set for significance in all cases.

Results and Discussion

During the present study, a total of 907 ticks were collected from 520 donkeys and 4 horses from four cities in White Nile state, during the period from November 2014 to October 2015). The effects of some factors: location, seasons and animals' breed, sex and age were considered (Tables 1-7). The location's prevalence (frequency) percentage was 28.05% in Eldowaim and 30.15% in Elgitaina (eastern bank of the White Nile) and from the western bank of the White Nile: 17.56% in Rabak and 24.24% in Kosti. Such result could be justified that the region is open directly to Gezira Agricultural Scheme where animals are abundant. Additionally, the seasonal prevalence, in winter (November to February) was 37.77%; in summer (March to June) was 37.79% and in autumn (July to October) was 24.43%. Furthermore, the frequency by donkeys' breed was: Makadi (72.9%); Reefawi (15.46%) and Mixed (10.88%) and only 4 horses representing 0.76% (Table 8). The findings of a trial that made to determine ticks distribution between donkey's breeds indicated that statistically significant difference was observed in infestation rate. Most of equine owners to gain more benefit from such animals and for their prestige look while riding them, they do care about their feed, cleaning such animals by peasants' hands or acaricides and though show good body condition. Moreover, by animal sex, the frequency was 77.09% females and 22.90% males. The difference in tick infestation rate between host sex groups was statistically significant ($p < 0.05$) be attributed by high population of female donkeys which are more easier dealing with than males, that may reduce the number of male examined. Additionally, male donkeys mainly used for transportation and hence they are in close supervision by their owner for tick infestation. Such situations may reduce the number of ticks on animals in general, as observed in the present study. However, the age percentual frequency was accounted for prevalence as: <5 years (24.62%); 5-10 years (53.82%); 11-15 years (18.51%); 16-20 years (1.91%) and >20 (1.14%). This might be justified as the

young animals mostly untied and dwelling around their mothers and homes and have access to contact with other species of animals, therefore, the higher the chance of getting more ticks infestation.

The collected 907 ticks were comprising 4 genera: *Rhipicephalus* (*Boophilus*), *Amblyomma* and *Hyalomma*. The data showed the species composition of ticks feeding on donkeys as: *R. (B.) decoloratus* (38.92% of the total) and 5.67% and 94.33% female and males ticks, respectively; *R. evertsi evertsi* (22.93% of the total) and 80.77% and 19.23% female and males ticks, respectively; *R. camicasi* (7.72% of the total) and 40% and 60% female and males ticks, respectively; *R. guilhoni* (7.72% of the total) and 32.86% and 67.14% female and males ticks, respectively; *A. lepidum* (6.84% of the total) and 67.74% and 32.26% female and males ticks, respectively; *Hy excavatum* (5.29% of the total) and 62.50% and 37.50% female and males ticks, respectively; *Hy impeltatum* (4.30% of the total) and 25.64% and 74.36% female and males ticks, respectively; *Hy. anatolicum* (2.98% of the total) and 59.26% and 40.74% female and males ticks, respectively; *Hy rufipes*, (2.09% of the total) and 15.79% and 84.21% female and males ticks, respectively; *Hy dromedarii* (1.21% of the total) and 27.27% and 72.73% female and males ticks, respectively. However, regarding the 4 horses (2 males and 2 females) infected with 114 ticks in winter, at El Diwaim and Rabak. These 114 tick species were: *R. (B.) decoratus* (42 ticks); *R. evertsi evertsi* (21 ticks); *R. camicasi* (12 ticks); *Hy. excavatum* (16 ticks); *Hy. impeltatum* (7 ticks); *Hy. rufipes* (6 ticks); *Hy. anatolicum* (5 ticks); *A. lepidum* (4 ticks) and *Hy. dromedarii* (1 tick).

Historically, since the Sudan independence, several tick species were reported in all states across central Sudan. For instance, *A. exornatum*, *A. lepidum*, *A. variegatum* and *H. scupense*, *H. dromedarii*, *H. excavatum*, *H. impeltatum*, *H. impressum*, *H. marginatum*, *H. rufipes*, *H. anatolicum*, *R. evertsi evertsi*, *R. praetextatus* and *R. sanguineus*. *R. (B.) decoloratus* and *R. (Boophilus) annulatus* [15, 18, 32]. Regarding this state White Nile (the region of the present study) and the Blue Nile ecosystem state, it was found 24 tick species infesting livestock and wildlife in these areas [19]. Ticks on donkeys and other animals were investigated in Kassala state, eastern Sudan [16]. *R. evertsi evertsi* and *R. sanguineus*; *Hy. excavatum* and *Hy. rufipes* on equines, and other domestic livestock were reported in eastern Sudan [20]. However, *H. anatolicum*, *H. dromedarii*, *H. rufipes* and *R. evertsi evertsi* were collected from horses in Khartoum state (on the northern border of the present study region) [21]. Additionally, in Gadarif state (eastern Sudan), reported *H. anatolicum* (as the predominant species on horses), *H. dromedarii*, *R. evertsi evertsi* and *R. sanguineus* [22]. Furthermore, he also reported the dominant tick species infesting horses in Kosti (White Nile state) as *H. anatolicum*, *H. dromedarii*, *R. evertsi evertsi* and *R. sanguineus*. Moreover, in El Obeid (Kordofan state, on the western border of the White Nile state), and Khartoum state he identified *H. dromedarii*, *R. evertsi evertsi* and *R. sanguineus* on horses.

It seems as the worldwide interest in ticks and tick-borne diseases has increased in recent years because of the direct and indirect effect on their host and hence significantly threat any successful livestock production thus interfere with national economy. Equine, especially donkey, represent an important contribution to human welfare in vulnerable households in Sudan for transportation, bringing water and pull carts. People ride on equine become in direct contact with ticks on animals. Alkhurma hemorrhagic fever was detected

in Italian travelers returning from Egypt after bitten by ticks while riding on camels [29]. Additionally the CCHFV was reported in Kordofan region, bordering the study region [25]. In fact, the present results stated that 50% of the tick species are *Hyalomma*. Apparently, *Hyalomma* species are the main virus vectors. Therefore, the present survey may demonstrate some of the constraints to utilize such animals with precautions. Additionally, such recorded results could enlighten the importance of a national program to precisely investigating the disease and successfully monitor and reduce the population of the vector(s). Finally, it could be recommended to adopt training in integrated tick management and prevention of tick-associated disease for public health officials and control operators in addition to the homeowners. Regarding equine Babesiosis, Table (9) shows that out of the 524 equines, 158 donkeys (30.2%) were detected positives with *Babesia* spp and non of the 4 horses' samples. However, Table (9) shows that the highest *Babesia* spp prevalence were diagnosed in eastern bank proportionally more than in the western bank. By site it is higher in Rabak followed by Kosti, Elgitaina and Elduiam. Additionally, in the study animals, *Babesia* spp was observed frequently in autumn, increases in winter and peaked in summer.

Nevertheless, more than twenty one ixodid ticks species, including *Hyalomma* and *Rhipicephalus*, are listed as vectors for equine piroplasms [37] however, in the present study, for financial shortage, only blood parasitological diagnostic method was performed and ticks were not examined as vectors. It is crucial however, to examine such ticks' species as vectors in a foreseeable future. The present results show low number of *Babesia* spp in autumn season may be due to decrease number of sampling in such donkey's markets in this rainy season of the year. In the rainy season donkeys are used in agricultural practices away from such markets, in addition to difficulty in reaching them because of limiting transportation in such rural areas that lacks paved roads.

In the present study, *Babesia equi* was the causal organisms of equine Babesiosis, a febrile tick borne disease of donkeys. It is a hazardous disease that responsible for morbidity and mortality of equines worldwide. It has a considerable veterinary economic importance. For instance, the prerequisite for the import of any horses in the United States, Canada, Australia and Japan is seronegativity for *Babesia* species [38, 39]. Additionally, as infected equines can carry the piroplasms in their blood for some years they may become reservoirs for new infection. Literature survey revealed that rare report documented equine piroplasmosis in Sudan. Using thin blood smears and CF test, the epidemiology of the disease in Khartoum state was studied [21]. Among 80 horses examined they reported 16% with typical clinical signs of piroplasmosis and 20% with Babesial parasites in their blood smears. Therefore, more detailed work is badly needed. Additionally, in Sudan that borders eight countries in addition to free movement of about 140 millions of livestock, there is a serious risk of disseminating such diseases and entrance of novel exotic diseases/pathogens especially in overlooked remote rural area.

In fact, several diseases affecting humans are originated from animals, and also endanger the economy via augmenting the cost of safeguarding both humans and animals. For alleviation of poverty in the rural areas in Sudan, sustainable increase in livestock production would be significantly enhance this possibility. To achieve such goal, it is crucial to adopt advance diseases forecasting, beside conventional assays, adoption of novel molecular biological techniques that now

frequently used for the rapid and sensitive diagnosis at nano and picogram level ^[40]. In addition to the availability of suitable drugs to treat equine piroplasmiasis and safer and quality vaccination coverage, with reasonable transport facilities for in time delivery of veterinary services beside education of animal's owners and labors ^[41]. Therefore, in

Sudan, serious attention and extra precaution should be concerned of in respect to afford satisfy financial support to have state-wise adequate infrastructure research facilities for wise implementation of such disease and vectors' control measures especially in remote rural areas where the majority of livestock and equines are.

Table 1: Prevalence of ticks infesting donkeys according breed, sex and age in White Nile State, Sudan, 2015

Location	Frequency	Percent	Breed	Frequency	Percent	Age	Frequency	Percent
Dowaim	147	28.05	Makadi	382	72.9	<5	129	24.62
Gitaina	158	30.15	Reefawi	81	15.46	5-10	282	53.82
Rabak	92	17.56	Mixed	57	10.88	11-15	97	18.51
Kosti	127	24.24	Horse	4	0.76	16-20	10	1.91
Total	524	100	Total	524	100	>20	6	1.14
						Total	524	100
Season	Frequency	Percent	Sex	Frequency	Percent			
Winter	198	37.77	Female	404	77.09			
Summer	198	37.79	Male	120	22.9			
Autumn	128	24.43	Total	524	100			
Total	524	100						

Table 2: Prevalence of hard tick (Acari: Ixodidae) species feeding on donkeys in White Nile State, Sudan, 2015

Species	RBdecF	RBdecM	RevsF	RevsM	RcamF	RcamM	RgulF	RgulM	AlepF	AlepM
No collected	20	333	168	40	28	42	23	47	42	20
Females + males	0	353	0	208	0	70	0	70	0	62
% from total	0	38.92%	0	22.93%	0	7.72	0	7.72%	0	6.84%
% of ticks sex	5.67%	94.33%	80.77%	19.23%	40%	60%	32.86%	67.14%	67.74%	32.26%
Species	HexcF	HexcM	HimpF	HimpM	HanaF	HanaM	HrufF	HrufM	HdrmF	HdrmM
No collected	30	18	10	29	16	11	3	16	3	8
Females + males	0	48	0	39	0	27	0	19	0	11
% from total	0	5.29%	0	4.30%	0	2.98%	0	2.09%	0	1.21%
% of ticks sex	62.50%	37.50%	25.64%	74.36%	59.26%	40.74%	15.79%	84.21%	27.27%	72.73%

Male = M and Female = F

Rhipicephalus (Boophilus) decoloratus (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Tables 3: Means ($\pm$ SE) of hard tick (Acari: Ixodidae) species feeding on donkeys by location in White Nile State, Sudan, 2015

Locations	HdrmF	HdrmM	HrufM	HexcF	HexcM	HanaF	HanaM	HimpF	HimpM
Dowaim	0	1 $\pm$ 0	0	1 $\pm$ 0	1.25 $\pm$ 0.25	1 $\pm$ 0	0	1 $\pm$ 0	2 $\pm$ 0
Gitaina	1 $\pm$ 0	1 $\pm$ 0	0	0	3 $\pm$ 0	0	0	0	0
Rabak	0	1 $\pm$ 0	6 $\pm$ 0	5.75 $\pm$ 2.75	2 $\pm$ 1	5 $\pm$ 0	1.5 $\pm$ 0.5	0	5.34 $\pm$ 2.18
Kosti	1 $\pm$ 0	0	0	0	0	2 $\pm$ 0	0	0	1 $\pm$ 0
Total	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	4.17 $\pm$ 2.01	1.71 $\pm$ 0.36	2.25 $\pm$ 0.95	1.5 $\pm$ 0.5	1 $\pm$ 0	3.8 $\pm$ 1.53
Location	RBdecF	RBdecM	RevsF	RevsM	RgulF	RgulM	RcamF	RcamM	AlepF
Dowaim	1 $\pm$ 0	2.3 $\pm$ 0.49	1.94 $\pm$ 0.34	1.37 $\pm$ 0.26	1.2 $\pm$ 0.2	2 $\pm$ 0	1 $\pm$ 0	2 $\pm$ 0.45	1.5 $\pm$ 0.5
Gitaina	0	2.63 $\pm$ 0.33	1.87 $\pm$ 0.31	1.33 $\pm$ 0.33	1 $\pm$ 0	1.5 $\pm$ 0.29	2.33 $\pm$ 1.33	1 $\pm$ 0	1 $\pm$ 0
Rabak	3 $\pm$ 2	3.41 $\pm$ 0.95	2.54 $\pm$ 0.92	1.67 $\pm$ 0.67	0	1 $\pm$ 0	1 $\pm$ 0	5.5 $\pm$ 3.5	4 $\pm$ 0
Kosti	1 $\pm$ 0	2.46 $\pm$ 0.38	2 $\pm$ 0.68	1.5 $\pm$ 0.5	0	1 $\pm$ 0	1 $\pm$ 0	1 $\pm$ 0	15 $\pm$ 0
Total	1.8 $\pm$ 0.8	2.65 $\pm$ 0.25	2.04 $\pm$ 0.28	1.44 $\pm$ 0.18	1.14 $\pm$ 0.14	1.41 $\pm$ 0.19	1.57 $\pm$ 0.57	2.4 $\pm$ 0.78	4.6 $\pm$ 2.68

Male = M and Female = F

Rhipicephalus (Boophilus) decoloratus (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Table 4: Means ($\pm$ SE) of hard tick (Acari: Ixodidae) species feeding on donkeys by Season in White Nile State, Sudan, 2015

Seasons	Hdrmf	HdrmM	HrufM	HexcF	HexcM	HanaF	HanaM	HimpF	HimpM
Winter	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	4.17 $\pm$ 2.01	1.71 $\pm$ 0.36	3 $\pm$ 2	1.5 $\pm$ 0.5	1 $\pm$ 0	3.8 $\pm$ 1.53
Summer	0	0	0	0	0	1 $\pm$ 0	0	0	0
Autumn	0	0	0	0	0	2 $\pm$ 0	0	0	0
Total	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	4.17 $\pm$ 2.01	1.71 $\pm$ 0.36	2.25 $\pm$ 0.95	1.5 $\pm$ 0.5	1 $\pm$ 0	3.8 $\pm$ 1.53
Seasons	RBdecF	RBdecM	RevsF	RevsM	RgulF	RgulM	RcamF	RcamM	AlepF
Winter	1.8 $\pm$ 0.8	2.99 $\pm$ 0.32	2.09 $\pm$ 0.34	1.57 $\pm$ 0.23	1.17 $\pm$ 0.17	1.14 $\pm$ 0.14	1 $\pm$ 0	3 $\pm$ 1.05	5.25 $\pm$ 3.33
Summer	0	1.59 $\pm$ 0.17	1.42 $\pm$ 0.23	1 $\pm$ 0	1 $\pm$ 0	1.64 $\pm$ 0.36	2.33 $\pm$ 1.33	1 $\pm$ 0	2 $\pm$ 0
Autumn	0	2.78 $\pm$ 1.06	2.45 $\pm$ 0.97	1 $\pm$ 0	0	1.25 $\pm$ 0.25	1 $\pm$ 0	0	0
Total	1.8 $\pm$ 0.8	2.65 $\pm$ 0.25	2.04 $\pm$ 0.28	1.44 $\pm$ 0.18	1.14 $\pm$ 0.14	1.41 $\pm$ 0.19	1.57 $\pm$ 0.57	2.4 $\pm$ 0.78	4.6 $\pm$ 2.66

Male = M and Female= F

Rhipicephalus (*Boophilus*) *decoloratus* (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Table 5: Means ($\pm$ SE) of hard tick (Acari: Ixodidae) species feeding on donkeys by animal breed in White Nile State, Sudan, 2015

Breed	Hdrmf	HdrmM	HrufM	HexcF	HexcM	HanaF	HanaM	HimpF	HimpM
Makadi	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	3 $\pm$ 2	1.6 $\pm$ 0.4	1.33 $\pm$ 0.33	1.5 $\pm$ 0.5	1 $\pm$ 0	3.67 $\pm$ 2.18
Reefawi	0	0	0	1 $\pm$ 0	0	0	0	0	1 $\pm$ 0
Mixed	0	0	0	2 $\pm$ 0	1 $\pm$ 0	0	0	0	0
Horse	0	0	0	0	0	0	0	0	0
Total	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	2.4 $\pm$ 1.17	1.5 $\pm$ 0.34	1.33 $\pm$ 0.33	1.5 $\pm$ 0.5	1 $\pm$ 0	3 $\pm$ 1.68
Breed	RBdecF	RBdecM	RevsF	RevsM	RgulF	RgulM	RcamF	RcamM	AlepF
Mkadi	1.8 $\pm$ 0.8	2.25 $\pm$ 0.21	1.73 $\pm$ 0.17	1.53 $\pm$ 0.21	1.2 $\pm$ 0.2	1.21 $\pm$ 0.11	1 $\pm$ 0	1.8 $\pm$ 0.37	1.5 $\pm$ 0.5
Reefawi	0	1.81 $\pm$ 0.23	1.43 $\pm$ 0.2	1 $\pm$ 0	1 $\pm$ 0	1.5 $\pm$ 0.29	1 $\pm$ 0	1 $\pm$ 0	0
Mixed	0	4.27 $\pm$ 0.99	3.14 $\pm$ 2.14	1 $\pm$ 0	0	2 $\pm$ 1	5 $\pm$ 0	1 $\pm$ 0	8 $\pm$ 7
Horse	0	2 $\pm$ 0	2 $\pm$ 0	0	0	0	0	3 $\pm$ 0	0
Total	1.8 $\pm$ 0.8	2.38 $\pm$ 0.19	1.84 $\pm$ 0.24	1.44 $\pm$ 0.18	1.14 $\pm$ 0.14	1.41 $\pm$ 0.19	1.57 $\pm$ 0.57	1.67 $\pm$ 0.29	4.75 $\pm$ 3.42

Male = M and Female= F

Rhipicephalus (*Boophilus*) *decoloratus* (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Table 6: Means ($\pm$ SE) of hard tick (Acari: Ixodidae) species feeding on donkeys by animal sex in White Nile State, Sudan, 2015

Sex	Hdrmf	HdrmM	HrufM	HexcF	HexcM	HanaF	HanaM	HimpF	HimpM
Female	0	1 $\pm$ 0	6 $\pm$ 0	2.4 $\pm$ 1.17	1.8 $\pm$ 0.49	2.25 $\pm$ 0.95	2 $\pm$ 0	1 $\pm$ 0	4.5 $\pm$ 1.75
Male	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	13 $\pm$ 0	1.5 $\pm$ 0.5	0	1 $\pm$ 0	0	1 $\pm$ 0
Total	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	4.17 $\pm$ 2.01	1.71 $\pm$ 0.36	2.25 $\pm$ 0.95	1.5 $\pm$ 0.5	1 $\pm$ 0	3.8 $\pm$ 1.53
Sex	RBdecF	RBdecM	RevsF	RevsM	RgulF	RgulM	RcamF	RcamM	AlepF
Female	1.8 $\pm$ 0.8	2.66 $\pm$ 0.29	2.15 $\pm$ 0.37	1.57 $\pm$ 0.23	1.25 $\pm$ 0.25	1.39 $\pm$ 0.23	1.67 $\pm$ 0.67	2.5 $\pm$ 1.31	5.25 $\pm$ 3.33
Male	0	2.64 $\pm$ 0.5	1.78 $\pm$ 0.31	1 $\pm$ 0	1 $\pm$ 0	1.5 $\pm$ 0.29	1 $\pm$ 0	2.25 $\pm$ 0.48	2 $\pm$ 0
Total	1.8 $\pm$ 0.8	2.65 $\pm$ 0.25	2.04 $\pm$ 0.28	1.44 $\pm$ 0.18	1.14 $\pm$ 0.14	1.41 $\pm$ 0.19	1.57 $\pm$ 0.57	2.4 $\pm$ 0.78	4.6 $\pm$ 2.66

Male = M and Female= F

Rhipicephalus (*Boophilus*) *decoloratus* (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Table 7: Prevalence of hard tick (Acari: Ixodidae) species feeding on donkeys by animal age in White Nile State, Sudan, 2015

Age	Hdrmf	HdrmM	HrufM	HexcF	HexcM	HanaF	HanaM	HimpF	HimpM
<5	1 $\pm$ 0	0	0	0	3 $\pm$ 0	1.5 $\pm$ 0.5	1 $\pm$ 0	0	0
5-10	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	5.75 $\pm$ 2.75	1.5 $\pm$ 0.5	3 $\pm$ 2	2 $\pm$ 0	1 $\pm$ 0	3.8 $\pm$ 1.53
11-15	0	1 $\pm$ -	0	1 $\pm$ 0	1.5 $\pm$ 0.5	0	0	0	0
16-20	0	0	0	0	0	0	0	0	0
>20	0	0	0	0	0	0	0	0	0
Total	1 $\pm$ 0	1 $\pm$ 0	6 $\pm$ 0	4.17 $\pm$ 2.07	1.71 $\pm$ 0.36	2.25 $\pm$ 0.95	1.5 $\pm$ 0.5	1 $\pm$ 0	3.8 $\pm$ 1.53
Age	RBdecF	RBdecM	RevsF	RevsM	RgulF	RgulM	RcamF	RcamM	AlepF
<5	1 $\pm$.	2.19 $\pm$ 0.25	1.81 $\pm$ 0.3	1.17 $\pm$ 0.17	1.33 $\pm$ 0.33	1.75 $\pm$ 0.25	1 $\pm$ 0	2 $\pm$ 0.58	1 $\pm$.
5-10	3 $\pm$ 2	2.88 $\pm$ 0.25	2.24 $\pm$ 0.41	1.4 $\pm$ 0.27	1 $\pm$ 0	1.43 $\pm$ 0.29	1.8 $\pm$ 0.8	3 $\pm$ 2	5.5 $\pm$ 3.23
11-15	1 $\pm$ 0	2.76 $\pm$ 0.42	1.45 $\pm$ 0.21	2.5 $\pm$ 0.5	1 $\pm$.	1 $\pm$ 0	0	2 $\pm$ 0.58	0
16-20	0	1 $\pm$.	0	0	0	0	0	0	0
>20	0	2 $\pm$.	0	0	0	0	0	0	0
Total	1.8 $\pm$ 0.8	2.65 $\pm$ 0.25	2.04 $\pm$ 0.28	1.44 $\pm$ 0.18	1.14 $\pm$ 0.14	1.41 $\pm$ 0.19	1.57 $\pm$ 0.57	2.4 $\pm$ 0.78	4.6 $\pm$ 2.66

Male = M and Female= F

Rhipicephalus (*Boophilus*) *decoloratus* (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Rhipicephalus guilhoni* (Rgul), *Amblyomma lepidum* (Alep), *Hyalomma excavatum* (Hexc), *Hyalomma impeltatum* (Himp), *Hyalomma anatolicum* (Hana), *Hyalomma rufipes* (Hruf), *Hyalomma dromadarii* (Hdrm)

Table 8: Prevalence of hard tick (Acari: Ixodidae) feeding on horses by location in White Nile State, Sudan, 2015

Location	Age	sex	breed	Season	HdrmM	HrufM	HexcF	HexcM	HanaF	HimpM	RBdecM	RevsF	RcamM	AlepF	Total
Dowaimiwaime	<5	Female	horse	Winter	0	0	0	0	0	0	2	2	3	0	7
Rabak	5 to 10	Male	horse	Winter	1	0	0	3	5	7	8	0	9	4	37
Rabak	<5	Female	horse	Winter	0	6	13	0	0	0	16	7	0	0	42
Rabak	5 to 10	Male	horse	Winter	0	0	0	0	0	0	16	12	0	0	28
Total					1	6	13	3	5	7	42	21	12	4	114

Male = M and Female= F

Hyalomma dromadarii (Hdrm), *Hyalomma rufipes* (Hruf), *Hyalomma excavatum* (Hexc), *Hyalomma anatolicum* (Hana), *Hyalomma impeltatum* (Himp), *Rhipicephalus (Boophilus) decoloratus* (RBdec), *Rhipicephalus evertsi evertsi* (Revs), *Rhipicephalus camicasi* (Rcam), *Amblyomma lepidum* (Alep)

Table 9: Prevalence *Babesia* species infection among examined donkeys in relation to season and location in White Nile State, Sudan, 2015

Location	<i>Babesia</i> species		
	Winter	Summer	Autumn
Elduim	28.3	11.7	7.4
Elgitaina	15.0	40.0	18.4
Rabak	51.6	55.2	31.3
Kosti	44.7	36.7	35.5

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