Prevalence of ticks (Acari: Ixodidae) and *Theileria lestoquardi* in sheep at El Huda and El Nuhud animals production research stations, Sudan

Abdelmonim Magzoub1 · Ahmed El Ghali1 · Mohammed O. Hussien2 · Yasir Juma1 · Sara B. Mohammed3

Received: 18 March 2020 / Accepted: 29 September 2020 / Published online: 13 October 2020
© Indian Society for Parasitology 2020

**Abstract** A cross-sectional study was performed 200 blood samples and 314 tick samples in El Huda and El Nuhud animals production research stations, Sudan, in May (summer) and December (winter) in 2016, to determine the prevalence of *Theileria lestoquardi* in sheep and the potential risk factors associated with the infection. A total of 200 blood samples and 314 tick samples were collected from El Huda (n = 103 blood, 97 tick) and El Nuhud (n = 97 blood, 217 tick) stations. Data on the risk factors, such as age, sex, ecotype of sheep, body condition score and seasons were recorded. The overall prevalence of *Theileria lestoquardi* was 13% (26/200) using PCR. A significant variation in the prevalence of *Theileria lestoquardi* was observed between the stations and the ecotype of sheep (*p* ≤ 0.05), whereas the highest prevalence was recorded in El-Huda station (19.4%) as well as in Shugor (22.8%). Other risk factors, like age, sex, body condition, and seasons were not found to be significantly associated with infection. However, the highest prevalence rate was recorded in old animals (21.6%) than the other, in males (17.9%) than females (12.2%), in animals with poor body condition (26.1%) than the other, and in winter (16%) than summer (10%). Four tick species i.e. *Rhipicephalus evertsi evertsi* (63.1%), *Hyalomma dromedarii* (8.8%), and *Hyalomma impeltatum* (14.3%) were recorded in El Nuhud station. While in El Huda station, only *Rhipicephalus evertsi evertsi* (79.4%), *Hyalomma anatolicum* (20.6%) were recorded. This study revealed that 13% of sheep were suffering from *Theileria lestoquardi* which is a considerable number at the stations. Therefore, further epidemiological investigations on disease throughout the year are required in order to set a well-coordinated control program.

**Keywords** *Theileria lestoquardi* · Sheep · Ticks · PCR · Sudan

**Introduction**

Tick-borne diseases (TBDs) are present throughout the world, particularly in the tropical and subtropical regions. These diseases are considered a significant threat to global food security (Jabbar et al. 2015). Ovine theileriosis is a tick-borne disease caused by *Theileria* spp, which is an apicomplexan protozoan parasite that exists in a wide zone of northern Africa, south-eastern Europe, central and western Asia and in India (Uilenberg 1981). Of the *Theileria* species affecting sheep and goats, *T. lestoquardi* is considered the major pathogenic species that causes malignant ovine theileriosis (Luo and Yin 1997; Mehlhorn et al. 1994). On the other hand, *T. separata* and *T. ovis* cause either low or non-pathogenic theileriosis in goats and sheep (Hassan et al. 2015).

*Theileria lestoquardi* is mainly transmitted by *Hyalomma anatolicum* (Taha and El Hussein 2010). The typical clinical symptoms of *T. lestoquardi* infections are high fever, enlargement of the lymph nodes, emaciation, anorexia, intermittent diarrhoea or constipation and weight...
loss (Tageldin et al. 2005). In Sudan, malignant ovine theileriosis was reported by El Ghali and El Hussein (1995) and Ahmed (1999), who illustrated that the disease caused significant losses among sheep.

The diagnosis of theileriosis is mainly based on the blood smears examination. However, this method is unable to differentiate between the species due to morphological similarity (Salih et al. 2015). PCR has become a favored method of diagnosis in epidemiological studies as this method, which allows the detection of parasite at the low level of parasitaemia and differentiation between Theileria species (Tuli et al. 2015; Altay et al. 2005).

El Huda and El Nuhud animal production research stations are considered the most important research centers in Sudan that constructed for many purposes such as production and distribution of improved animals for breeding purposes and research on various aspects of animal production (FAO 2005). In order to improve the control measures against the tick-borne diseases, including malignant ovine theileriosis. It is necessary to know the prevalence of the disease in the target populations. Moreover, the detection of these organisms is necessary for a better understanding of their epidemiology (Oura et al. 2004).

Referring to all above, this study was carried out to determine the prevalence of Theileria lestoquardi in sheep and the potential risk factors associated with the infection in El Huda and El Nuhud Animal Production Research Stations.

Materials and methods

Study areas

El Huda station is located in Al Gezira State at approximately 14°55’S latitude and 32°91’E longitude, about 150 km south of Khartoum (capital city of Sudan) and about 90 km north-west of Wad Medani (Fig. 1). The animal herd consists of three ecotypes of Sudanese desert sheep namely Shugor, Dubasi and Watish (Ahmed et al. 2018).

El Nuhud station is located in West Kordofan State at latitude 12°42’N and longitude 28°25’E, which is found in savannah zone (Fig. 1). The animal herd consists of two ecotypes of Sudanese desert sheep namely Hamari and Kabashi (APRC 2016).

Collection of samples and study design

Blood samples

A total number of 103 and 97 sheep were randomly selected from El Huda station and El Nuhud station, respectively, in May and December 2016. Blood samples were collected directly from the Jugular veins into EDTA containing tubes, which preserved in transport cooler box with thermometer. Meanwhile, individual animal data including age, sex, ecotype and body condition score were recorded. The age of the animal was estimated by the method explained by De-Lahunta and Habel (1986) and classified into three groups; animals over 3 years (old animal), animals between 1 and 3 years (middle age animal) and animals under 1 year old (young animal) (Table 1). The body condition scores of animals were evaluated and classified into three groups; poor, moderate and good body condition. The ecotypes of sheep were classified into; Shugor, Dubasi, Watish, Hamari and Kabashi (Table 1).

Tick samples

Ticks were collected from their predilection sites from 200 sheep and from the ground of both stations by using a pair of blunt metal forceps. The ticks were individually stored in a labelled tube containing 70% ethanol. Under a dissecting microscope, ticks were identified based on morphological characteristics using the key identification guide (Walker et al. 2003).

Molecular detection

DNA extraction

DNA was extracted from the whole blood samples using the phenol–chloroform extraction method following the protocol described by Sambrook et al. (1989). The isolated DNA stored at -20°C until used. For quality assessment, 2 µl of extracted DNA were analyzed on 1.5% agarose gel.

Polymerase chain reaction (PCR)

Two primer pairs [Forward 5’-GTGCCGCAAGTGAGTCA-3’ and Reverse 5’-GGACTGATGAGAACGATGAG-3’] were used to amplify a 730 bp fragment of the 18S rRNA gene of T. lestoquardi according to the method described by Taha et al. (2011). The positive control was prepared from T. lestoquardi culture (Central Laboratory, Sudan), while PCR mixture was used without DNA template as a negative control.

Springer
PCR was performed in a final reaction volume of 20 μl containing; 6 μl of H₂O, 2 μl of each primer, 5 μl of genomic DNA and 5 μl of Maxime PCR Premix (iNtRON Biotechnology, Korea). The Maxime PCR Premix contained; 1 × reaction buffer (10 ×), 2.5 U of iTaq™ DNA Polymerase (5 U/μl), 2.5 mM of each dNTPs and 1 × Gel loading buffer. The amplification was performed with an initial denaturation at 94 °C for 3 min followed by 35 cycles of 94 °C for 1 min, 56 °C for 1 min, 72 °C for 1 min and final extension step at 72 °C for 7 min. The PCR products were visualized on 1.5% agarose gel stained with Ethidium Bromide.

Data analysis

The IBM SPSS 16 Package was utilized in the analysis. Descriptive statistics were determined for all quantitative variables. Data were analysed using Chi square test to calculate the degree of association between risk factors and the prevalence of *Theileria lestoquardi* infection. Differences were considered significant at \( p \leq 0.05 \).

Results

The overall prevalence

The overall prevalence of *T. lestoquardi* was 13% (26/200) using PCR (Table 2). A significant variation in the
Prevalence of \( T.\) lestoquardi was observed between the two stations (\( p \) value = 0.005), whereas El Huda station 19.4% (20 out of 103) having a significantly higher prevalence than El Nuhud station 6.2% (6 out of 97) (Table 2).

### Prevalence of \( T.\) lestoquardi by stations, ecotype, age, sex, body condition scores and seasons

There was significant variation (\( p \leq 0.05 \)) in the prevalence of \( T.\) lestoquardi between the ecotype of sheep (\( p \) value = 0.050), where the highest prevalence rate was reported in Shugor (22.8%), followed by Watish (18.2%), Dubasi (14.3%), Hamari (7.4%) and the lowest prevalence was reported in Kabashi (3.4%) (Table 2).

Risk factors like age, sex, body condition score and season were not significantly associated with the prevalence of \( T.\) lestoquardi in sheep (\( p > 0.05 \)) (Table 2). Animals of the age group > 3 years old (old animal) showed the highest prevalence rate (21.6%) whereas animals of the age group between 1 and 3 years old (middle age animal) showed the lowest prevalence rate (12.2%), while no infection was observed in the animal less than 1 year old (young animal) (Table 2). The higher infection rate was observed in male (17.9%) compared with female (12.2%) as shown in Table 2.

The prevalence of the infection based on the body condition score (BCS) was (13.8%) in good body condition animals, followed by moderate body condition (9.8%) and the highest prevalence of \( T.\) lestoquardi was reported in animals with poor body conditions (26.1%). The higher infection rate was observed during winter (16%) compared with summer (10%) (Table 2).

### Tick species

In December 2016, a total of 97 ticks belonging to 2 species were collected from El Huda station, whereas a total of 217 ticks belonging to 4 species were collected from and El Nuhud station. \( Rhipicephalus \) evertsi evertsi and \( Hyalomma \) anatolicum were the only two species of ticks were recorded in El Huda station, while in El Nuhud station in
addition to above two species *Hyalomma dromedarii* and *Hyalomma impeltatum* were isolated as well (Table 3).

**Discussion**

In small ruminants, ovine theileriosis is considered as one of the most significant diseases particularly in tropics and subtropics that leads to economic losses in sheep and goat (Zaeem et al. 2010). Among the various species of *Theileria*, *T. lestoquardi* is the most pathogenic species infecting sheep and goats, causing malignant ovine theileriosis, a severe lymphoproliferative disease with high morbidity and mortality rate in sheep (Naz et al. 2012). The overall prevalence of *T. lestoquardi* was 13% as detected by PCR test. This finding was slightly lower than the previous reports, where the prevalences was 21% in district Lahore, Pakistan using PCR (Durrani et al. 2011) and 20% in Khartoum State, Sudan using indirect fluorescent antibody test (Hassan et al. 2018). The difference in the prevalence rate might be due to the variation in the geographical area and in the sensitivity of the diagnostic tests (Aziz and Al-Barwary 2019; Dharanesha et al. 2017).

The Chi square analysis showed that the station (locality) and the ecotype were the two risk factors associated significantly with the infection with *T. lestoquardi*. The highest prevalence was recorded in El Huda station (19.4%) compared with El Nuhud (6.2%). This result is in agreement with Khan (Khan et al. 2017) who demonstrated that small ruminant above 2 years was more susceptible to infection with theileriosis than other groups of animals in Pakistan. These results could attribute to the fact that the newborn animals received antibodies against *Theileria* spp through colostrum, which in turn results in the low prevalence of theileriosis among these animals (Toye et al. 2013). In addition, the young animal had less exposure time to ticks infestation compared with old animal (Hassan et al. 2018).

Although in the current study a slightly higher prevalence rate was reported in males (17.9%) than females (12.2%), this difference was not significant. This result is in agreement with Osman (Osman et al. 2017) and Taha (Taha et al. 2015) who demonstrated the highest prevalence rate of *T. lestoquardi* in male sheep than females. In contrast, the results of this study disagree with Naz et al. (2012) and Rehman et al. (2010) who found greater positivity of *Theileria* spp in female than male. This variation may be due to the big difference in the sample size of male and female included in our study, where the number of females was 6 times more than male. Another fact that could also explain this variation where that majority of female sheep are kept indoors for breeding (APRC 2016).

Although in the current study a slightly higher prevalence rate was reported in males (17.9%) than females (12.2%), this difference was not significant. This result is in agreement with Khan (Khan et al. 2017) who demonstrated that small ruminant above 2 years was more susceptible to infection with theileriosis than other groups of animals in Pakistan. These results could attribute to the fact that the newborn animals received antibodies against *Theileria* spp through colostrum, which in turn results in the low prevalence of theileriosis among these animals (Toye et al. 2013). In addition, the young animal had less exposure time to ticks infestation compared with old animal (Hassan et al. 2018).

Table 3 Number and sex of ticks recorded in El Nuhud and El Huda station in December 2016

| Species                        | Male | Female | Male | Female | Male | Female | Male | Female | Total (n = 314) |
|-------------------------------|------|--------|------|--------|------|--------|------|--------|----------------|
| H. impeltatum                 | 0    | 0      | 0    | 0      | 7    | 13     | 43   | 34     | 97             |
| H. dromedarii                 | 12   | 19     | 9    | 13     | 18   | 12     | 90   | 47     | 217            |
| H. anatolicum                 | 31(14.3%) | 19 (8.8%) | 30 (13.8%) | 137 (63.1%) |

**Table 3** Number and sex of ticks recorded in El Nuhud and El Huda station in December 2016

Moreover, the environmental conditions like temperature and rainfall impact on the vectors, which in turn affect on the transmission of the disease (Brand and Keeling 2017). The Chi square analysis showed that the station (locality) and the ecotype were the two risk factors associated significantly with the infection with *T. lestoquardi*. The highest prevalence was recorded in El Huda station (19.4%) compared with El Nuhud (6.2%). This result could be attributed to the fact that the majority of the sheep that exist in El Huda station are mainly raised along river banks, where the environmental conditions are favorable for the tick vector to survive and reproduce (Salih et al. 2003; Ahmed 1999).

Among the Sudanese sheep ecotypes, Shugor showed the highest infection rate with *T. lestoquardi* (22.8%) compared with the other ecotypes. The variation in the susceptibility among the Sudanese sheep ecotypes was also illustrated by El Imam et al. (2015), who found that desert ecotype was the most susceptible ecotype. Moreover, the effect of the host genetics on the susceptibility or resistance to parasite among sheep breeds has been demonstrated in several studies (Guo et al. 2016).

The results showed that the prevalence of *T. lestoquardi* was higher in old sheep (21.6%) compared with other (*p > 0.05*). This result is in agreement with Khan (Khan et al. 2017) who demonstrated that small ruminant above 2 years was more susceptible to infection with theileriosis than other groups of animals in Pakistan. These results could attribute to the fact that the newborn animals received antibodies against *Theileria* spp through colostrum, which in turn results in the low prevalence of theileriosis among these animals (Toye et al. 2013). In addition, the young animal had less exposure time to ticks infestation compared with old animal (Hassan et al. 2018).

Although in the current study a slightly higher prevalence rate was reported in males (17.9%) than females (12.2%), this difference was not significant. This result is in agreement with Osman (Osman et al. 2017) and Taha (Taha et al. 2015) who demonstrated the highest prevalence rate of *T. lestoquardi* in male sheep than females. In contrast, the results of this study disagree with Naz et al. (2012) and Rehman et al. (2010) who found greater positivity of *Theileria* spp in female than male. This variation may be due to the big difference in the sample size of male and female included in our study, where the number of females was 6 times more than male. Another fact that could also explain this variation where that majority of female sheep are kept indoors for breeding (APRC 2016).

Based on the body condition, the results illustrated that the prevalence of *T. lestoquardi* was higher in animals with poor body condition (26.1%). This could explain the well-known fact that the animal with poor body condition has a weak immune system, which in turn raises the susceptibility of the animal to infectious diseases (Hamsho et al. 2015).

Although there was a variation in the prevalence of *T. lestoquardi* between summer (10%) and winter (16%). There was no significant association between the prevalence of infection and season. In many tropical and sub-
tropical countries, the transmission of tick-borne diseases may be continuous throughout the year and the vector can be active most of the year even in small number (FAO 1983).

*Rhipicephalus evertsi evertsi* was the predominant species of tick in El Huda station (79.4%) and El Nuhud station (63.1%). Similarly, Hayati et al. (2020) reported that 51.6% of the ticks collected from Al Gezira State was *Rhipicephalus evertsi evertsi*. Moreover, the present of this species in Kordofan, where El Nuhud station is located, was reported in several studies (El Ghali and Hassan 2012).

Based on the findings of this study, it is concluded that the infection with *T. lestoquardi* was higher in El Huda station compared with El Nuhud using PCR. On the other hand, a variable like the ecotype of sheep is significantly associated with the infection with *T. lestoquardi*. Therefore, attention should be given to prevent and control the disease, especially where the prevalence of the disease is higher.

**Conclusion**

The present study reflects that *T. lestoquardi* is an important tick-borne problem in sheep at El Huda and El Nuhud animals production research stations, Sudan. Adverse effects of this disease on health and production of the sheep needs further investigation on the epidemiology of the disease throughout the year using molecular detection of *T. lestoquardi* in different tick species.

**Acknowledgements** We thank the staff members of the Central Veterinary Research Laboratory, Sudan for providing excellent assistance in the lab.

**Compliance with ethical standards**

**Conflict of interest** The authors declare no conflicts of interest in relation to this work.

**Ethical approval** All procedures performed in the study involving animals were in accordance with the ethical standards of the Institutional Ethics Committee of Sudan University of Science and Technology, Decision number DSR-IEC-01-016.

**References**

Ahmed BM (1999) Studies on epizootiology of *Theileria lestoquardi* (nomen novem) in River Nile State, Sudan. M.Sc. Dissertation, Nile Valley University, Sudan

Ahmed HDM, Ahmed AM, Salih DA, Hasan SK, Masri MM, Altayb HN, Khaier MAM, Hussien MO, El Hussein AM (2018) Prevalence, first molecular identification and characterization of *Theileria lestoquardi* in Sheep in Alhuda National Sheep Research Station, Al Gezira State, Sudan. Asian J Biol 7(2):1–9

Altay K, Dumani N, Holman PI, Aktas M (2005) Detection of *Theileria ovis* in naturally infected sheep by nested PCR. Vet Parasitol 127(2):99–104

APRC (2016) Animal Production Research Centre, Animal Resources Research Corporation. Ministry of Animal Resources, Range and Fisheries, Khartoum, Sudan

Aziz KJ, Al-Barwary LTO (2019) Epidemiological study of equine piroplasmosis (*Theileria equi* and *Babesia caballi*) by microscopic examination and competitive-ELISA in Erbil Province North-Iraq. Iran J Parasitol 14(3):404–412

Brand SP, Keeling MJ (2017) The impact of temperature changes on vector-borne disease transmission: *Culicoides* midges and blue-tongue virus. J R Soc Interface 14(128):20160481

De-Lahunta A, Habel RE (1986) Applied Veterinary Anatomy. W.B. Saunders Company, Philadelphia

Dharanesha NK, Giridhar P, Byregowda SM, Venkatesh MD, Ananda KJ (2017) Seasonal prevalence of blood parasitic diseases in crossbred cattle of Mysore and its surrounding districts of Karnataka. J Parasit Dis 41(3):773–777

Durrani AZ, Younus M, Kamal N, Mehmoood N, Shakoori AR (2011) Prevalence of ovine *Theileria* species in district Lahore, Pakistan. Pak J Zool 43:57–60

El Ghali AA, El Hussein AM (1995) Diseases of livestock in EdDamer Province, River Nile State, Sudan: a two-years retrospective study. Sud J Vet Sci Anim Husb 34:37–45

El Ghali AA, Hassan SM (2012) Ticks infesting animals in the Sudan and Southern Sudan: past and current status. Onderstepoort J Vet Res 79(1):E1–E6

El Imam AH, Hassan SM, Gameel AA, Elhussein AM, Taha KM, Salih DA (2015) Variation in susceptibility of three Sudanese sheep ecotypes to natural infection with *Theileria lestoquardi*. Small Rumin Res 124:105–111

FAO (1983) Tick-borne livestock diseases and their vectors. In: Ticks and tick-borne diseases selected articles from the world animal resources. Food and Agriculture Organization. Roma, Italy

FAO (2005) First Report on: The State of Genetic Resources in Sudan Livestock. In: Country reports on the state of animal genetic resources. Food and Agriculture Organization. Roma, Italy

Guo Z, González JF, Hernandez JN, McNielly TN, Corripio-Miyar Y, Frew D, Morrison T, Yu P, Li RW (2016) Possible mechanisms of host resistance to *Haemonchus contortus* infection in sheep breeds native to the Canary Islands. Sci Rep 6:26200

Hamsho A, Tesfamarym G, Megersa G, Megersa M (2015) A cross-sectional study of bovine babesiosis in Tetele District, Borena Zone, Southern Ethiopia. J Vet Sci Technol 6(3):1–4

Hassan MA, Raoofi A, Lotfollahzadeh S, Javanbakht J (2015) Clinical and cytological characteristics and prognostic implications on sheep and goat *Theileria* infection in north of Iran. J Parasit Dis 39(2):190–193

Hassan SA, Hassan SM, Hussein MO, El Haj LM, Osman MM, Ahmed RE, Abdel Gadir SO, El Hussein AM, Salih DA (2018) Prevalence of ticks (Acari: Ixodidae) and *Theileria lestoquardi* antibodies in sheep and goats in Khartoum State, Sudan. Sud J Vet Res 33:31–37

Hayati MA, Hassan SM, Ahmed SK, Salih DA (2020) Prevalence of ticks (Acari: Ixodidae) and *Theileria annulata* infection of cattle in Gezira State, Sudan. Parasite Epidemiol Control 10:e00148

Jabbar A, Abbas T, Sandhu ZU, Saddiqi HA, Qamar MF, Gasser RB (2015) Tick-borne diseases of bovines in Pakistan: major scope for future research and improved control. Parasites Vectors 8:283

Khan MA, Khan MA, Ahmad I, Khan MS, Anjum AA, Durrani AZ, Hameed K, Kakar IU, Wajid A, Ramazan M (2017) Risk factors assessment and molecular characterization of *Theileria* in small ruminants of Balochistan. J Anim Plant Sci 27(4):1190–1196
Luo J, Yin H (1997) Theileriosis of sheep and goats in China. Trop Anim Health Prod 29:8S–10S

Mehlhorn H, Schein E, Ahmed JS (1994) Theileria. In: Kreier JP (ed) Parasitic protozoa, part 2, vol 7. Academic Press, San Diego, pp 217–304

Nas S, Maqbool A, Ahme S, Ashra K, Ahmed N, Saeed K, Latif M, Iqbal J, Ali Z, Shafi K, Nagra IA (2012) Prevalence of Theileriosis in small ruminants in Lahore, Pakistan. J Vet Anim Sci 2:16–20

Osman TM, Ali AM, Hussein MO, El Ghali A, Salih DA (2017) Investigation on Theileria lestoquardi infection among sheep and goats in Nyala, South Darfur State, Sudan. Insights Vet Sci 1:017–023

Oura CAL, Bishop RP, Wampande EM, Lubega GW, Tait A (2004) Application of a reverse line blot assay to the study of haemoparasites in cattle in Uganda. Int J Parasitol 34:603–613

Rehman Z, Khan MS, Avais M, Aleem M, Shabbir MZ, Khan JA (2010) Prevalence of Theileriosis in sheep in Okara district, Pakistan. Pak J Zool 42:639–643

Salih DA, El Hussein AM, Hayat M, Taha KM (2003) Survey of Theileria lestoquardi antibodies among Sudanese sheep. Vet Parasitol 111(2003):361–367

Salih DA, El Hussein AM, Singla LD (2015) Diagnostic approaches for tick-borne haemoparasitic diseases in livestock. J Vet Med Anim Health 7(2):45–56

Sambrook J, Fritsch ER, Maniatis T (1989) Molecular cloning: a laboratory manual. Cold Spring Harbor Laboratory Press, New York

Tageldin MH, Fadiya AA, Sabra AA, Ismail SI (2005) Theileriosis in sheep and goats in the Sultanate of Oman. Trop Anim Health Prod 37:491–493

Taha KM, El Hussein AM (2010) Experimental transmission of Theileria lestoquardi by developmental stages of Hyalomma anatolicum ticks. Parasitol Res 107:1009–1012

Taha KM, Salih DA, Ahmed MB, Enan KA, Ali AM (2011) First confirmed report of outbreak of malignant ovine theileriosis among goats in Sudan. Parasitol Res 109:1525–1527

Taha HA, Shoman SA, Alhadligh NM (2015) Molecular and serological survey of some haemoproteoza, rickettsial and viral diseases of small ruminants from Al-Madinah Al Munawarah, KSA. Trop Biomed 32(3):511–523

Toye P, Handel I, Gray J, Kiara H, Thumbi S, Jennings A, van Wyk IC, Ndila M, Hanotte O, Coetzer K, Woolhouse M, Bronsvoort M (2013) Maternal antibody uptake, duration and influence on survival and growth rate in a cohort of indigenous calves in a smallholder farming system in western Kenya. Vet Immunol Immunopathol 155(1–2):129–134

Tuli A, Singla LD, Sharma A, Bal MS, Filia G, Kaur P (2015) Molecular epidemiology, risk factors and haematological alterations induced by Theileria annulata in dairy animals of Punjab (India). Acta Parasitol 60(3):378–390

Uilenberg G (1981) Theileria species of domestic livestock. In: Irvin AD, Cunningham MP, Young S (eds) Advances in control of Theileriosis. Martinus Nijhoff Publishers, The Hague, pp 4–37

Walker AR, Bouattour A, Camicas JL, Estrada-Peña A, Horak IG, Latif AA, Pagram RG, Preston PM (2003) Ticks of domestic animals in Africa: a guide to identification of species. Bioscience Reports, University of Edinburgh

Zaeem M, Haddadzadeh H, Khazraeinia P, Kazemi B, Bandehpour M (2010) Identification of different Theileria species (Theileria lestoquardi, Theileria ovis, and Theileria annulata) in naturally infected sheep using nested PCR–RFLP. Parasitol Res 108:837–843

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.