SM Tropical Medicine Journal ISSN: 2573-363X

Review Article

Study on Current Status of Bovine Trypanosomiasis and Its Spatio-Temporal Distribution of Vectors in Ethiopia: Systematic Review

Daniel Tamirat WeldeMariam[1*] and Emishaw Demise[2]

[1]Department of Veterinary Public Health, Haramaya University College of Veterinary Medicine, Ethiopia

[2]Department of Veterinary Epidemiology, Haramaya University College of Veterinary Medicine, Ethiopia

Abstract

Trypanosomiasis is a disease complex caused by several species of unicellular protozoal parasites of the genus Trypanosoma. In Ethiopia, bovine trypanomiasis is highly prevalent in low lands of tsetse infested areas and distribution is found to be widespread covering most parts of Western and south-western parts of the country and some species are distributed throughout the countries. The most important trypanosomes, in terms of economic loss in domestic livestock, are tsetse transmitted species: T. Congolese, T. vivax, and T. brucei. Trypanosomiasis remains a serious challenge causes economic losses and main constraint of livestock production and rural development in the country. In Ethiopia, the temporal and spatial distribution of bovine Trypanosomiasis, information on dynamics of tsetse, tsetse-infested areas and seasonal occurrence of bovine trypanomiasis is limited. But tsetse flies are biological vectors of African Trypanosomiasis in animals. Their distribution and prevalence are most influenced by spatial factors such as climate, vegetation, and land utilization. It is transmitted from infected animals to susceptible hosts both mechanical and biological vectors and is characterized by enlargement of lymph nodes, and chronic emaciation, this disease can be diagnosed by clinical signs, or direct and indirect parasitological diagnosis. Once infection of bovine trypanomiasis has happened, it can be treated by diminazene aceturate, homidium bromide, homidium chloride, and isometamidium and quinapyramine sulfate. Bovine trypanomiasis can be controlled by early treatment of infected animals, and vector control. Thus, it is recommended that appropriate use of antiprotozoal drugs, restriction of animal movement, and integrated prevention and control program should be implemented to eradicate trypanomiasis and protozoal disease.

Keywords: African Animal Trypanosomosis; Bovine; Ethiopia; Spatio-temporal distribution

Abbreviations: AAT: African Animal Trpanosomiasis; Ab: Antibody; Ag: Antigen; DNA: Deoxyribose Nucleic Acid; ELISA: Enzyme Linked Imminosorbent Assay; GDP: Growth Domestic Product; IFAT: Immunoflorence Antibody Test; IHT: Indirect Haemaglutination Test; ITS-PCR: Internal Ranscribed Spacer-polymerase Cell Reaction; NTTICC: National Tsetse, Trypanosomiasis Investigation and Control Center; OIE: Office of International des Epizooties; PCR: Polymerase Chain Reaction; SIT: Sterile Insect Technique; SNNPR: Southern Nation Nationalities People's Region; RBC: Rade Blood Cell; Rpm: Revolution per Minute

INTRODUCTION

African animal trypanomiasis (AAT) is a most important constraint to livestock production in tropical Africa [1], and is considered a threat to poverty alleviation programs in the continent [2]. Disease is widely distributed with about 50 million heads of cattle and livestock species being at risk [3]. Ethiopia has a huge livestock population in Africa, and the livestock sector plays a significant role in the national economy and livelihood of farmers and pastoralists [4] also the subsector contributes about 16.5% of the national gross domestic product (GDP) and 35.6% of agricultural GDP [5]. Despite this huge livestock number, productivity is too low and even below average for most Eastern and Sub-Saharan African countries, due to several complex and interrelated factors, such as widespread diseases, poor genetic potential of local breeds, and inefficiency of livestock development services [6]. Among Those, Trypanosomosis is one of the major animal health constraints to livestock production and agricultural development [7].

Submitted: 08 May 2024 | **Accepted:** 21 May, 2024 | **Published:** 22 May, 2024

***Corresponding author:** Daniel Tamirat WeldeMariam, Department of Veterinary Public Health, Haramaya University College of Veterinary Medicine, Haramaya, Ethiopia

Citation: WeldeMariam DT, Demise E, (2024) Study on Current Status of Bovine Trypanosomiasis and Its Spatio-Temporal Distribution of Vectors in Ethiopia: Systematic Review. SM Trop Med J 6: 9.

Trypanosomiasis is caused by unicellular, flagellated protozoan parasites that belong to the genus Trypanosomes which are found in the blood or tissues of vertebrates including livestock and wildlife [8]. vector includes several species of tsetse flies and they are grouped into three categories: *Glossina pulpis* group (savanna areas), *Glossina fusca* group (forest areas), and *Glossina palpalis* group (river and lake areas). Currently, in Ethiopia, about 220,000 km^2 of tsetse belt areas with five species of tsetse flies namely *G. Pallidipes, G. morsitans, G. fuscipes, G. tachnoides and G. longipennis* [9]. The disease is caused by pathogenic species of trypanosomes transmitted cyclically by the tsetse fly (*Glossina* species) and non-cyclically by or biting flies except *T. equiperdum*, which follows an epidemiological route of transmission among the equine population in its endemic areas. Trypanosome species affecting livestock in Ethiopia are *T.congolense, T. Vivax, and T. brucei* in cattle, sheep, and goats. The most important trypanosome species that affect cattle, sheep, and goats are *T. congolense Trypanomiasis vivax and Trypanomiasis brucei.* Annual losses to the national economy are estimated to exceed $200 million because of mortality and morbidity of livestock, denied access to land resources, and costs of controlling this disease [10]. The distribution of Trypanosomes is dynamic due to climatic change, ecological disturbances, and human interventions. Tsetse flies in Ethiopia are confined to southern and western regions between a longitude of 33° and 38°E, and a latitude of 5° and 12°N [11]. Tsetse-infested areas lie in the lowlands and river valleys of Abbay (Blue Nile), Baro, Akobo, Didessa, Ghibe, and Omo [12]. Out of nine regions of Ethiopia five (Oromia, SNNPR, Amhara, Beninshangul Gumuz, and Gambella) are infested with more than one species of tsetse flies [13].

Economic impacts developed are direct losses (loss of production, mortality, and abortion), cost of control (cost of drugs, transportation cost to field and operators salaries), and indirect losses (loss of potential production) [14]. Trpanosomiasis is threatening agricultural production and cattle breeding more severely than any or livestock disease [15]. Information on temporal and spatial dynamics of tsetse and trypanosomes remains limited and may be a reason that control strategies are less effective [16]. So knowledge of temporal, dry, and wet seasons, prevalence of trypanosomosis, and distribution of tsetse fly are important when devising appropriate strategies for control of seasonal problems [16].

Methods used to reduce trypanosomosis and its effects are the use of drugs for curative and prevention and the use of trypanotolerant cattle (Muturu and N'Dama) [17]. According to NTTICC, tsetse-transmitted animal Trypanosomiasis remains one of the largest causes of livestock production losses in Ethiopia. Therefore,

To date, there is no review of existing literature on spatio-temporal distribution of Trypanomiasis. Thus, this review was made to highlight the current status of bovine trpanosomiasis in Ethiopia, summarize, the spatial and temporal distribution of vectors in Ethiopia, and compile species of trypanosomes affecting cattle.

LITERATURE REVIEW

Background of Trypanosomiasis

Definition of Disease: Trypanosomiasis (African) or Names: *Nangana, Tsetse Disease, Tsetse Fly Disease, African animal Trypanosomiasis* (AAT) is a parasitic disease that causes anemia, loss of condition, and emaciation in livestock caused by several species of unicellular protozoan parasites of phylum Sarcomastigophora, order Kinetoplastida, family Trypanosomatidae and genus Trypanosoma. It is mainly transmitted cyclically by *Glossina* (Tsetse flies), but also transmitted mechanically by several biting flies (*Tabanids, Stomoxyis*, etc.) [18]. Disease can affect various species of mammals but, from an economic point of view, tsetse-transmitted Trypanosomiasis is particularly important in cattle. It is mainly caused by *T. Congolese, T. vivax,* and, to a lesser extent, *T. brucei* [2].

The name trypanosome is derived from the Greek words trypan- (borer) and soma (body) because of the corkscrew-like motion [19]. Trypanosome consists of a single cell varying in size from 8 to 50 µm. Different trypanosome species differ in morphological characteristics as described by appearance, shape, and size between various species, allowing specific identification [20].

Etiology

Trypanosomes are flagellated protozoan parasites that live in the blood or body fluids of vertebrate hosts and swim in body fluids by flagellum, a boring way between cells. Generally possess a Kinetoplastida and undergo cyclical development in an arthropod vector. Biological adaptations, morphology, and pathogenicity are fascinating and are being extensively studied [21]. Trypanosomiasis outside the "tsetse belt" is caused by mechanically biting flies; the main etiological agent mechanically transmitted is *T. vivax* [22].

Epidemiology

The epidemiology of African animal trypanosomosis is highly dependent on parasite, vector, and host factors. Trypanosome species occur in a variety of genotypes with different strains, virulence, immunogenicity, and response to chemotherapeutic agents. The severity of the disease also depends on the species and strain of trypanosomes involved. Since parasite infects a wide range of animals including wild animals which constitute reservoirs of disease, the epidemiology of trypanosomosis is extremely complicated. degree of risk to which domestic animals are exposed to trypanosomosis depends on the species and density of tsetse present, the infection rate in tsetse, species, and strain of trypanosomes, source of infection (wild or domestic animals) and feeding preference of flies [23].

Risk Factors

Host Factors:

The effect of infection varies with the host in that most wild animals and some domestic ones, establish a balance with a parasite and remain as clinically normal carriers for long- periods. The susceptibility of cattle to trypanosomosis depends on breed, age, behavior, previous exposure, and health status. Some trypanotolerant breeds of cattle, indigenous to Africa can tolerate light to moderate challenges with tsetse flies by limiting the multiplication of trypanosomes in blood and by apparently warding off infection, especially *T.vivax* [24]. The level of trypanotolerance varies, depending on both genetic and environmental origin. Crossbreeds of indigenous Taurine and Zebu animals are also more tolerant than pure breed zebu [25]. Indigenous zebus are trypano-susceptible and West African Bos-taurus breeds are trypanotolerant, i.e. can survive and be productive without treatment under trypanosomiasis risk. Exotic imported ruminants (e.g. improved dairy cattle) are more severely affected than local genotypes [2]. Four Ethiopian cattle breeds Abigar, Gurage, Horo, and Sheko are related to trypanotolerance [26].

Environmental Factors:

The density of the tsetse population in the area and the level of contact with the host will determine the level of infection. Trekking of cattle through tsetse-infested vegetation is a risk, nomadic farmers face from time to time and the risk is even greater where cattle routes converge, for example, at major bridges or watering holes [27]. Agricultural and industrial developments generally lead to a lowering of tsetse density by destroying its habitat, whereas, the establishment of game or forest reserves provides large numbers of preferred hosts or a suitable habitat for tsetse, respectively. Herds located near such reserves are therefore at a higher risk [28].

Pathogen Factors:

The severity of the disease varies with the species and age of the animal infected and the species of trypanosome involved. In cattle, *T. Vivax* generally produces a higher level of parasitemia than other species. And since its life cycle in tsetse is also shorter; *T. Vivax* is more readily transmitted than when animals are newly introduced into a tsetse-infested area. Higher parasitemia also facilitates mechanical transmission. *T. Congolese* and *T. Vivax* are highly pathogenic for cattle and *T. Brucei* infections are generally regarded as being of low pathogenicity [29].

Life cycle

The life cycle of trypanosome in tsetse involves cyclical development for varying lengths of time, depending on species and ambient temperature. Most tsetse transmission begins when blood from a trypanosome-infected animal is ingested by a tsetse fly [30]. Trypanosome loses its surface coat, multiplies in fly, on a surface coat, and becomes infective. *Trypanosoma brucei* species migrate from the gut to proventriculus to the pharynx and eventually to salivary glands; the cycle for *T. Congolense* stops at the hypopharynx and salivary glands are not invaded; the entire cycle for *T. Vivax* occurs in the proboscis. Animal - The infective form in the tsetse salivary gland is referred to as the metacyclic form. Incubation period trypanosomiasis specious *is T. Congolense* usually becomes apparent in 4–24 days, *T. Vivax* in 4–40 days, and *T. Brucei* highly variable. Infections with more virulent isolates have a shorter incubation period [31].

Pathogenesis

Pathogenesis of Trypanosomosis in most species is a progressive, but not always fatal disease and its main features are anemia, tissue damage, and immunosuppression. Metacyclic trypanosomes are inoculated

intradermally as fly feeds. multiply at this site provoking a local skin reaction (*Chancre*), which is most pronounced in a fully susceptible host and may be slight or absent with some strains or species of trypanosomes Within *chancre,* metacyclic parasites change to Trypomastigote form, enter the bloodstream directly or through lymphatic and initiate characteristic intermittent parasitemia. in behavior thereafter depends largely on the species of Trypanosome transmitted and host [32].

Trypanosoma vivax usually multiplies rapidly in the blood of cattle and is evenly dispersed throughout the cardiovascular system, whereas *T. congolense* tends to be aggregated in small blood vessels and capillaries of the heart, brain and skeletal muscle Both species exert effect mainly by causing severe anemia and mild to moderate organ damage. Anemia has a complex pathogenesis involving mainly increased erythrophagocytosis, some hemolysis, and dyshemopoiesis [33].

Geographical Distribution

The general distribution of tsetse flies is determined principally by climate and influenced by altitude, vegetation, and presence of suitable host animal [34]. Epidemiology of the animal Trypanosomosis is determined mainly by an ecology of tsetse fly which is found only in tropical Africa. Ethiopia is situated at the east end of the African tsetse belt and in Ethiopia, tsetse flies are confined to southwestern and northwestern regions between longitude 33° and 38 °E and latitude 5° and 12°N of an area covers 220,000 km^2 [35].

In Ethiopia, tsetse-infested areas lay in lowlands and also in river valleys of Blue Nile, Baro Akobo, Didessa, Ghibe, and Omo. Out of nine regions of Ethiopia five (Amhara, Beninshangul Gumuz, Gambella, Oromia, and Southern Nation Nationalities and peoples region) are infested with more than one species of tsetse flies [36]. To date, five species of *Glossina* (*G. morsitans submersions, G. pallidipes, G. Tachinoides, G. fuscipes and G. longipennis)* have been recorded from Ethiopia [37]. The spatial distribution of bovine trypanomiasis found in various parts of Ethiopia is different. most of the previous surveys were carried out in western and southwestern parts of Ethiopia, many published studies related to trypanomiasis have been found in various regional states, with a mean apparent prevalence of 8.17% in Amhara, 13.86% in Beninshangul Gumuz, 6.34% in Oromia, and 7.91% in Southern Nations, Nationalities, and Peoples' Regional State, whereas only a few published studies have been found in Afar and Tigray regions (Figure 1 & Table 1).

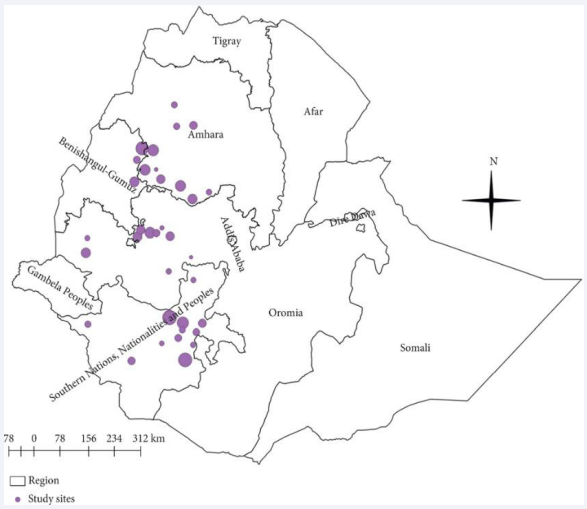

Figure 1 Observed spatial distribution of bovine trypanosomosis in Ethiopia.

Table 1: Summary of the mean apparent prevalence of bovine trypanomiasis in some regional states of Ethiopia. Source: Leta et al. [38]

Region	Prevalence %
Oromia	8.17
SNNPR	6.34
Amhara	13.86
Benshangul Gumuz	7.91

Temporal and spatial distribution of bovine trypanosomes in Ethiopia, information on temporal and spatial dynamics of tsetse and trypanosomes remain limited and may be a reason that control strategies are less effective [16]. The occurrence and impact of trypanosomosis, on the other hand, depends on the challenge, host distribution, livestock breeds, farming practices, and control practices. tsetse challenge is determined by the product of relative tsetse density, trypanosome prevalence in tsetse the proportion of meals obtained by the tsetse from a defined host, So knowledge of temporal, dry, and wet season, prevalence of Trypanosomiasis and distribution of tsetse fly are important when devising appropriate strategies for control of these problems [16] (Figure 2)(Table 2 & Table 3).

Mode of Transmission

Trypanosomiasis is a disease that is cyclically and mechanically transmitted by different species of tsetse flies tsetse flies become infected with trypanosomes when feeding on infected animals as well and trypanosome readily persists in areas free of tsetse, where it is transmitted mechanically by biting flies or contaminated needles, Syringes and surgical instruments [52].

Morbidity and Mortality

Trypanosoma vivax and *T. congolense* are considered to be major pathogens in cattle, while *T. brucei* is thought to be of lesser significance. Acute hemorrhagic syndrome caused by some *T. vivax* strains has a mortality rate of 6-35%, but, in general, *T. vivax* is considered to be less pathogenic for cattle than *T. congolense*. Some savannah-type strains of *T. congolense* are among the most virulent isolates [53].

Morbidity and mortality rates for African animal trypanomiasis are influenced by an animal's general health, as well as the strain and dose of infecting organisms. in susceptible cattle, some strains can result in 50-100% mortality within months. in Africa, Trypanosomiasis is now mostly a disease of high morbidity but low mortality in regions where sick animals are treated with trypanocidal drugs. Epizootics with high morbidity and mortality rates can be seen occasionally when susceptible livestock are introduced into endemic regions or when tsetse flies spread into an area where cattle are naïve [54].

Clinical Sign

The basic clinical syndrome appears after an incubation period of 8-20 days. Primary clinical signs are intermittent fever, anemia, and weight loss. Acute episodes last for a few days to a few weeks from which the animal dies or lapses into a subacute to the chronic stage, or the illness may be chronic from the beginning. Chronic cases may run a steady course, may be interrupted by periodic incidents of severe illness, or undergo spontaneous recovery [2].

Major clinical signs are intermittent fever, anemia, edema, lacrimation, enlarged lymph nodes, abortion, decreased fertility, loss of appetite, dull, anorexic, body condition and productivity, early death in acute forms, emaciation and eventual death in chronic forms often after digestive or nervous signs [55]. Superficial lymph nodes become visibly swollen, mucous membranes are pale, diarrhea occasionally occurs, and some animals have edema of the throat and underline. Estrus cycles become irregular, pregnant animals may abort, and semen quality progressively deteriorates. The animal becomes very emaciated and cachectic and dies within 2-4 months or longer. Thin, rough-coated, anemic, lethargic cattle

Table 2: The prevalence of bovine trypanomiasis 2016-2021 in some parts of Ethiopia.

Study area	Sample size	animal examined		Prevalence of positive animal %		positive animal		Reference
		M	F	M	F	M	F	
Chora District of Illuababora	332	151	181	39.3	47.1	17	29	Marta et al. [41]
Abeshige District of Gurage Zone,	498	234	264	15.8	9.4	37	25	Lemma et al. [42]
Dara district,Sidama zone	384	97	287	12	45	12.4	15.7	Migbaru et al. [43]
Sheka zone, and Eracha woreda		209	174	2	2.3	4	4	Yigzaw et al. [44]
Sayo district	860	416	83	3.27	1.2	2	1	Bakele and Desta. [45]
Tarcha Zuria District, Dawuro Zone		44	73	9.10	5.48	4	4	Madalcho. [46]
Damot WoydeDistrict, southern Ethiopia	144	61	83	3.27	1.2	2	1	Takele and Gechere. [47]
Jimma Arjo district, east wollega	819	490	329	5.3	3.1	26	10	Abdeta et al. [48]
West Gojjam zone	730	322	408	8.70	7.11	28	29	Lelisa and Meharenet. [49]
Hawa Galan District, kelem wollega zone	428	209	219	6.7	5.48	14	12	Tsegaye et al. [50]

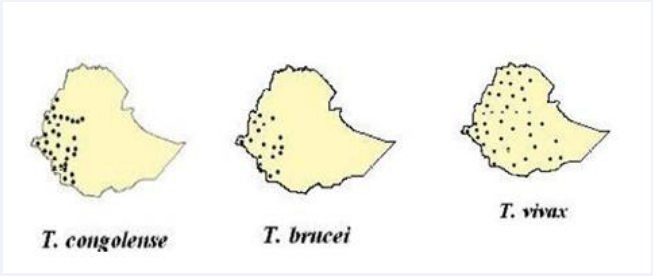

Figure 2 Presence of *T. congolense, T. brucei,* and *T. vivax* in livestock in Ethiopia. Source: Birhanu et al. [39]

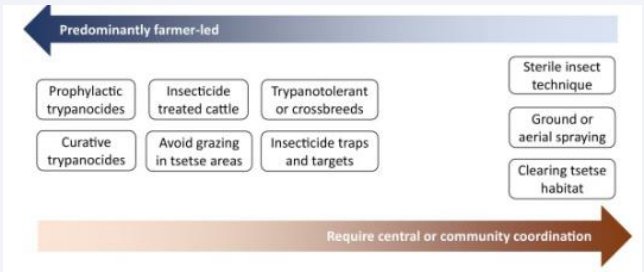

Figure 3 Control options for African animal trypanosomiasis (AAT) highlighting farmer versus community or centrally required coordination. Source: Richards et al. [40]

Table 3: Bovine trypanosome species reported in Ethiopia. Source: Desta and Lelisa. [51]

Trypanosomes	Vector	Mainly affected host	Regional distribution
T. congolense	Tsetse	Cattle	Amhara
T. brucei	Tsetse	Cattle	Benshangul-gumuz, gembella,Oromia and SNNPER
T. vivax	Biting flies	Cattle	All overEthiopia

with generalized lymph node enlargement are said to have a 'fly-struck' appearance. Cattle usually have a chronic course with high mortality, especially if it is poor nutrition or stress factors [56]. Furthermore, intercurrent bacterial, viral, or parasitic infections may mask or complicate basic clinical syndrome. Immune response to bacterial, and some viral, vaccines is also depressed but is restored if trypanocidal therapy is given at the time of vaccination [57].

Diagnosis

There are no pathognomonic signs that would help in pinpointing a diagnosis. Diagnosis of Trypanosomiasis in tsetse, domestic livestock is a basic requirement for epidemiological studies as well as for planning and implementing chemotherapy and for monitoring vector control operations. Accurate diagnosis of trypanosome infection in livestock is required for a proper appreciation of disease in any geographical locality.

Besides clinical diagnosis, parasitological, serological, and molecular methods with varying degrees of sensitivity and specificity are available for diagnosis of trypanosomosis [40]. On the other hand, *T. brucei* is rarely detectable by direct examination of cattle blood, even though infection can be confirmed through diagnostic methods [58].

Clinical Diagnosis:

The primary clinical signs are intermittent fever, anemia, and weight loss. Cattle usually have a chronic course with high mortality, especially if there is poor nutrition or other stress factors. Clinical diagnosis was found to have a good sensitivity (78%) but a low specificity (27%) when compared to parasitological tests [59]. It appears that treatment of cattle based on clinical examination may clear up to 87.5% or 78% of the cases that would be positive by either molecular or parasitological diagnosis, respectively. Under field conditions, in the absence of simple and portable diagnostic tools or access to laboratory facilities, veterinarians could rely on clinical signs and direct parasitological diagnosis to screen and treat cases of bovine trypanosomosis presented by farmers [60].

Parasitological examination

Dark ground/Phase contrast/ Buffy coat technique:

Buffy coat zone prepared in a micro hematocrit capillary filled with 70µl of blood and centrifuged for 5 minutes at 12000 rpm is examined for trypanosomes by cutting capillary tube to include 1 mm of erythrocytes and 1 cm of plasma. The Buffy coat is poured on a slide and covered with a 22 x 22 mm cover slip. Preparation is examined using a microscope with a phase contrast and dark ground illumination. The use of a 10x eyepiece in combination with a 25x objective gives optimal viewing by allowing large visual fields and sufficient magnification for ready identification of trypanosomes. This technique is the most sensitive of parasitological tests for detection of *T. congolense* and *T. vivax* detecting trypanosomes to an estimated level of just over 102 parasites per ml [39]. In addition, species identification based on size and movement is easier to assess [61].

Parasitological Diagnosis by Direct Examination

Wet Blood Film**:** This is made by placing a drop of blood on a microscope slide and covering it with a cover slip. Blood is examined microscopically using an x40 objective lens. Approximately 50-100 fields are examined. Trypanosomes can be recognized by movement among RBC. The method is simple, inexpensive, and gives immediate results depending on trypanosome size and movement of presumptive diagnosis can be made of trypanosome species.

Thick blood Smear technique: The method is simple and relatively inexpensive, but results are delayed because of the staining process. Trypanosomes are easily recognized by general morphology but may be damaged during the staining process. This may make it difficult to identify species [62].

Thin blood smear technique**:** Usually, both a thin and thick smear are made from the same sample. Thick smears contain more blood than thin smears and, hence, have a higher diagnostic sensitivity. While thin smears allow trypanosome species identification. Trypanosome species can be identified by following morphological characteristics (Criteria of OIE) trypanosome Vivax: 20-27 mm. long, undulating membrane is not obvious, free flagellum present at anterior end, posterior end rounded, and kinetoplast large and terminal. *T. brucei* is a polymorphic trypanosome species. Two distinctly different forms can be distinguished, i.e. a long slender form and a short stumpy form. Often, intermediate forms, possessing characteristics of both slender and stumpy forms, are observed. Cytoplasm often contains basophilic granules in stained specimens [63].

T.congolense: 8-25 mm (Small species), undulating membrane not obvious, free flagellum absent, posterior end rounded**,** kinetoplast is medium-sized and terminal, often laterally positioned. Although *T. congolense* is considered to be monomorphic, a degree of morphological variation is sometimes observed.

Serological Diagnosis: Serological methods are indirect methods for the diagnosis of trypanomiasis based on the detection of antibodies or circulating antigens of parasites. Most commonly used serological tests include indirect haemaglutination test (IHT), precipitation tests, indirect fluorescent antibody test (IFAT), and ELISA [64]. However, serological tests are used as tools for research, monitoring, and control surveys [65].

Antibody detection tests: Several antibody detection techniques have been developed to detect trypanosome antibodies for the diagnosis of African animal trypanomiasis [66]. however, the disadvantages of Sero-diagnosis are (i) antibody ELISAs are not species-specific because of strong cross-reactions between pathogenic trypanosome species [67] and (ii) the persistence of antibodies after a curative treatment or a self-cure is estimated to be on average of 3-4 months [68].

Antigen detection tests: assays detect circulating antigens of *T.congolense, T. vivax, and T. brucei* in the blood of infected animals. ELISA and field-oriented latex agglutination tests have been developed and used in Africa and some other countries. Antigen-detecting ELISA (Ag-ELISA) would have allowed the detection of circulating trypanosome antigens and therefore confirmed the occurrence of an active infection [69].

Molecular diagnosis: The method that is currently recommended for trypanosome diagnosis is molecular identification, due to high sensitivity and specificity [70]. The principle of molecular methods is to detect DNA sequences that are specific for trypanosome subgenus, species, subspecies, type, or strain. Several PCR-based techniques have been developed for the identification of trypanosome species [71].

Polymerase chain reaction (PCR): polymerase chain reaction is one of the most sensitive and specific diagnostic methods of AAT [72], and has overcome the constraints of parasitological and serological techniques [71]. PCR is based on the use of an enzyme, DNA polymerase, which amplifies sequences of DNA bases until sufficient material is produced to be detected [73]. Several studies have shown that PCR is a specific and more sensitive method in the diagnosis of trypanomiasis in experimental as well as natural infections, identifying parasites at the species level [74]. Currently, several PCR-based diagnostic assays have been developed to improve the detection of pathogenic trypanosomes [75]. Two internal transcribed spacer PCR (ITS-PCR) are used as universal primers as theyey can detect all pathogenic trypanosome species [76].

The main disadvantage of PCR is that it is very expensive in terms of cost, requires skilled manpower, and requires precision instruments and elaborate visualization methods [77]. to detect trypanosomes and avoid false positive results; it is possible to combine PCR and DNA probe technology [78].

Differential Diagnosis

Acute Trypanosomiasis with fever: babesiosis, anaplasmosis, theileriosis (east coast fever), Hemorrhagic septicemia, and Anthrax [79].

Chronic Trypanosomiasis with anemia and emaciation**:** helminthosis or haemoparasitoses [80].

Post Mortem Lesions

Gross lesions are nonspecific .lymph nodes and spleen are enlarged in the acute stage, and petechial are frequently found on serosal surfaces, particularly in the peritoneal cavity. Lymph nodes may be enlarged, normal, or atrophied in more prolonged cases; are not usually enlarged in chronically infected animals. Serous atrophy of fat and evidence of anemia are common, and subcutaneous edema, excessive fluid in body cavities and pericardial sac, pulmonary edema, and an enlarged liver may also be seen. The carcass may be wasted or emaciated. Some trypanosomes can

directly damage tissues, resulting in lesions such as keratitis or cardiac damage (e.g., myocarditis). Immune complexes also cause inflammation and damage in a variety of tissues including kidneys and blood vessels [81].

Economic and Zoonotic Importance

Tsetse flies infest 10 million square kilometers of Africa involving 37 countries. Hence, *Nangana* is today the most important disease of livestock in the continent [82]. Since *Nangana* is a wasting disease, affected animals are chronically unproductive in terms of milk, meat, manure, and traction, and the mortality rate can be high. disease in Africa costs livestock producers and consumers an estimated US$1340 million each year [47]. In Ethiopia land covered by tsetse infestation estimated at around 220,000km of fertile land remained unusable. This disease causes direct loss by mortality estimated to amount to 1.5 to 2 billion birr per year and indirect loss due to decreasing productivity and restriction from international livestock trade in the country

Animal pathogens do not infect humans, but animals can serve as reservoirs of *T. brucei Rhodesians* and *T. gambiense*, causes of human sleeping sickness, which are morphologically indistinguishable from *T. brucei*. Human infections result from tsetse bites, generally in game parks, forest reserves, and along streams or rural settings [83].

Treatment

The application of anti-typanosoma drugs has been the most widely practiced means of controlling trypanosomosis in domestic livestock since the early 1950s, either as curative or prophylactic drugs [74]. Trypanosomiasis can be treated with trypanocidal drugs for therapeutic and prophylactic purposes. Therapeutic drugs include diminazene aceturate, homidium bromide, and homidium chloride. Prophylactic drugs for cattle include homidium, homidium chloride, and isometamidium [37].

Control of vector

Controlling the vector of trypanomiasis remains theoretically the most desirable way of containing the disease [84]. The absence of eggs and a free larval stage in nature and the fact that pupal development occurs in the soil make the adult fly-only phase easily accessible for control purposes [85]. A wide variety of tsetse control techniques have been developed and have undergone trial. Those control techniques include ecological methods, the use of insecticides, the use of traps and targets use of insecticide-treated cattle use of sterile insect technique, or reducing the risk of exposure through changes in livestock management [86].

The choice of control method to be applied will depend on target zone, impact on environment, tsetse species, possibility of isolation of treated areas, possibilities of post-control land use, and available funding of operations now and for future [87]. However, eradication of tsetse is unlikely to succeed in the near future because tsetse interventions must be tediously planned at a continental scale to prevent tsetse re-infestation (Figure 3).

CONCLUSIONS AND RECOMMENDATION

Bovine trypanosomiasis is a serious protozoal disease that has a great economic impact throughout the world, especially in developing countries like Africa. In Ethiopia, bovine trypanosomiasis is the main problem of livestock production. This constraint in livestock production leads serious economic impact on the country's development. Bovine trypanomiasis (*Nangana*) is found in low lowlands of Ethiopia, especially in the "tsetse belt" like the rift valley, omo, borena, and metekel zone of Benshangul Gumuz region. Bovine trypanosomosis is mainly caused by three etiological agents, *T. vivax, T. congolense,* and *T. brucei.* Bovine Trypanosomosis is transmitted from infected animals to susceptible hosts both mechanical and biological vectors. The main biological vector is the tsetse fly that is found in the tsetse belt. *T. vivax* can be transmitted from infected animals to susceptible hosts both mechanically and biologically, but *T. Congolese* is mainly transmitted biologically. Bovine trypanomiasis show be diagnosed by clinical signs, direct parasitological diagnosis, and indirect parasitological diagnosis methods. Direct parasitological diagnosis includes wet blood film, thick blood smear, thin blood smear, and parasitological concentration technique. Indirect parasitological diagnosis includes Molecular testing, PCR, buffy coat techniques, and Hematocrit centrifugation test. Bovine trypanomiasis can be treated with both prophylactic and curative drugs. Drugs used for the treatment of bovine trypanomiasis include aceturate, Homidium, and Quinapyramine. This disease can be controlled by early treatment and vector control. Based on this, the following recommendations are forwarded.

- Use of Prompt integrated tsetse control strategy, and insect sterilization techniques (SIT) in highly prevalent areas.
- There is little information about the prevalence of trypanomiasis in endemic areas, in this regard, more research is enlargeable in the northern and southern parts of the country.
- Rational uses of trypanocidal and prophylactic drugs for sick animals as well as for control and prevention of trypanosome infestations.
- Rearing trypan-tolerant cattle breeds in endemic areas, restriction of animal movement is the best control method.
- Awareness creation about the disease and its transmission.

ACKNOWLEDGMENTS

We would like to thank Dr. Shihun Shimelis and Dereje Tamirat for providing their support in the preparation of this paper and we would like to extend our thanks to Haramaya University, College of Veterinary Medicine, we wish to express our profound gratitude for all financial supporters.

REFERENCES

1. Maichomo MW, Orenge CO, Gamba DO. Introduction of African Animal Trypanosomosis (AAT)/Nagana. Combating and Controlling Nagana and Tick-Borne Diseases in Livestock. IGI Global. 2021.
2. Gelaye A, Fesseha H. Bovine trypanosomiasis in Ethiopia: epidemiology, diagnosis and its economic impact-a review. J Biogen Sci Res. 2020; 2: 1-10.
3. Fesseha H, Mathewos M, Eshetu E, Tefera B. Babesiosis in cattle and ixodid tick distribution in Dasenech and Salamago Districts, southern Ethiopia. Sci Rep. 2022; 12: 1-11.
4. Abebe BK, Alemayehu MT, Haile SM. Opportunities and Challenges for Pastoral Beef Cattle Production in Ethiopia. Advan Agricul. 2022.
5. Shibru S, Sodo E. A review of challenges and opportunities of livestock marketing in the southern part of Ethiopia. Marketing. 2017; 34.
6. Getabalew M, Aliment T, Zewdie D. The milk processing: Status, challenges, and opportunities in Ethiopia. Int J Vet Sci Res. 2020; 6: 1-6.
7. Seyoum Z, Terefe G, Ashenafi H. Farmers' perception of impacts of bovine trypanosomosis and tsetse fly in selected districts in Baro-Akobo and Gojeb river basins, Southwestern Ethiopia. BMC Vet Res. 2013; 9: 214.
8. Krige AS. The secret life of wildlife trypanosomes: Australian trypanosomes and their association with ticks (Iodide) and biting flies (Tabanidae). The University of Western Australia. 2021.

9. Oyda S, Argaw S, Ayalew G, Alemayehu M, Mandado T. Effect of gibe–III Dam construction along Omo River Basin on prevalence of bovine trypanosomosis in selected localities of Loma District, Dawuro zone, Southern Region. 2020.

10. Lelisa K, Shimeles S, Bekele J, Sheferaw D. Bovine trypanosomosis and its fly vectors in three selected settlement areas of Hawa-Gelan district, western Ethiopia. Onderstepoort J Vet Res. 2014; 81: 1-5.

11. Fedesa H, Assefa K, Tekalegn D. Study on the spatial distribution of tsetse fly and prevalence of bovine trypanosomosis and other risk factors: a case study in Darimu District, Ilu Aba Bora Zone, and Western Ethiopia. J Pharm Alter Med. 2015; 7.

12. Meharenet B, Desta T, Lelisa K, Tsegaye M, Jula D. Epidemiology of bovine trypanosomosis and vector distribution in Didessa River Basin, Ethiopia. Acta Parasitol. 2020; 65: 743-749.

13. Alembo E. Prevalence of Bovine Trypanosomosis and Tsetse Fly Density in Different Regions of Ethiopia: A Review. J Vet Sci Technol. 2019; 10: 583.

14. Chanie M, Adula D, Bogale B. Socio-economic assessment of the impacts of trypanosomosis on cattle in Girja District, Southern Oromia Region, Southern Ethiopia. Acta Parasitol Glob. 2013; 4: 80-85.

15. Moti Y, DE Deken R, Thys E, Van den abbeele J, Duchateau L, Delespaux V. PCR and microsatellite analysis of diminazene aceturate resistance of bovine trypanosomes correlated to knowledge, attitude, and practice of livestock keepers in South-Western Ethiopia. Acta Trop. 2015; 146: 45-52.

16. Eyasu T, Mekuria S, Shiferaw D. Seasonal prevalence of trypanosomosis, Glossina density, and infection along the escarpment of Omo River, Loma district, southern Ethiopia. Heliyon. 2021; 7: e06667.

17. Ganyo EY, Boampong JN, Masiga DK, Villinger J, Turkson PK. Hematology of N'Dama and West African Shorthorn cattle herds under natural Trypanosoma vivax challenge in Ghana. F1000Res. 2018; 7: 314.

18. Abebe R, Gute S, Imon I. Bovine trypanosomosis and vector density in Omo-Ghibe tsetse belt, South Ethiopia. Acta Trop. 2017; 167: 79-85.

19. Botero A, Cooper C, Thompson CK, Clode PL, Rose K, Thompson RA. Morphological and phylogenetic description of Trypanosoma noyesi sp. Nov.: an Australian wildlife trypanosome within the T. cruzi clade. Protist. 2016; 167: 425-439.

20. Bargul JL, Jung J, Mcodimba FA, Omogo CO, Adung'a VO, Krüger T, et al. Species-specific adaptations of trypanosome morphology and motility to the mammalian host. PLoS Pathog. 2016; 12: e1005448.

21. Demarco SF. Molecular and Systems Analysis of Cell-Cell Communication and Social Behavior in Trypanosoma brucei, University of California, Los Angeles. 2019.

22. Suh P, Njiokou F, Mamoudou A, Ahmadou T, Mouhaman A, Garabed R. Bovine trypanosomiasis in tsetse-free pastoral zone of the Far-North region, Cameroon. J Vector Borne Dis. 2017; 54: 263.

23. Robi DT, Hurrisa BU, Gelalcha BD. Trypanotolerance Sheko cattle: an option for sustainable control of bovine trypanosomiasis. Open Vet Sci. 2021; 2: 81-90.

24. Ngumbi AF. Use and misuse of trypanocides and comparison of putatively Drug sensitive and resistant strains of trypanosome Congolense isolated from Tanzania. Sokoine University of Agriculture. 2020.

25. Bahbahani H, Tijjani A, Mukasa C, Wragg D, Alma then F, Nash O, et al. Signatures of selection for environmental adaptation and zebu×taurine hybrid fitness in East African Shorthorn Zebu. Front Genet. 2017; 8: 68.

26. Oyda S, Hailu M. Review on the prevalence of bovine trypanosomosis in Ethiopia. Afr J Agricult Res. 2018; 13: 1-6.

27. Olaniyan O. Vectors and transmission routes of animal Trypanosomiasis on the Jos Plateau north central Nigeria. 2016.

28. De beer CJ, Dicko AH, Ntshangase J, Moyaba P, Taioe MO, Mulandane FC, et al. A distribution model for Glossina brevipalpis and Glossina Austen in Southern Mozambique, Eswatini, and South Africa for enhanced area-wide integrated pest management approaches. PLoS Negl Trop Dis. 2021; 15: e0009989.

29. Habeeb IF, Chechet GD, Kwaga JK. Molecular identification and prevalence of trypanosomes in cattle distributed within the Jebba axis of the River Niger, Kwara state, Nigeria. Parasit Vectors. 2021; 14: 1-12.

30. Tessema W, Dana K. Prevalence and Associated Risk Factors of Bovine Trypanosomiasis in Ofa Wereda of Wolaita Zone, SNNPR, Ethiopia. American J Health Res. 2022; 10: 63-75.

31. Abu AH. Evaluation of antifertility and trypanocidal effects of hydroethanolic extract of hymenocardia acida (tul.) stem bark in rats. Department of veterinary physiology and pharmacology, faculty of veterinary. 2010; 12: 49.

32. Diarra B, Diarra M, Diall O, Bass B, Sanogo Y, Coulibaly E, et al. A national atlas of tsetse and African animal trypanosomosis in Mali. Parasit Vectors. 2019; 12: 466.

33. Lucius R, Roberts CW. Biology of Parasitic Protozoa. Biol Parasit. 2016; 52.

34. Lelisa K, Damena D, Kedir M, Feyera T. Prevalence of bovine trypanosomosis and apparent density of tsetse and other biting flies in Mandura District, Northwest Ethiopia. J Vet Sci Technol. 2015; 6: 229.

35. Hordofa KS, Haile G. A review on epidemiological distribution, impacts, and integrated control approach of tsetse fly. J Parasitol Vector Biol. 2017; 9: 122-131.

36. Semayat O, Maireg H. Review on prevalence of bovine trypanosomosis in Ethiopia. African J Agricult Res. 2018; 13: 1-6.

37. Mekonnen G, Mohammed EF, Kidane W, Nesibu A, Yohannes H, van reet N, et al. Isometamidium chloride and homidium chloride fail to cure mice infected with Ethiopian Trypanosoma evansi type A and B. PLoS Negl Trop Dis. 2018; 12: e0006790.

38. Leta S, Alemayehu G, Seyoum Z, Bezie M. Prevalence of bovine trypanosomosis in Ethiopia: a meta-analysis. Parasit Vectors. 2016; 9: 139.

39. Birhanu H, Fikru R, Said M, Kidane W, Gebrehiwot T, Hagos A, et al. Epidemiology of Trypanosoma evansi and Trypanosoma vivax in domestic animals from selected districts of Tigray and Afar regions, Northern Ethiopia. Parasit Vectors. 2015; 8: 212.

40. Richards S, Morrison LJ, Torr SJ, Barrett MP, Manangwa O, Mramba F, et al. Pharma to farmer: field challenges of optimizing trypanocide use in African animal trypanosomiasis. Trends Parasitol. 2021; 37: 831-843.

41. Marta T, Bedaso K, Gutu K, Eshetu G. Prevalence of bovine trypanosomosis and its vector apparent density in Chora District of Illuababora Western Oromia, Ethiopia. J Vet Med Animal Health. 2016; 8: 64-71.

42. Lemma F, Alemu S, Haile S. Prevalence of Bovine Trypanosomosis in Abeshige District of Gurage Zone, South Western Ethiopia. East African J Vet Animal Sci. 2017; 1: 1-6.

43. Migbaru KB, Zerihun S, Nateneal TB. Prevalence of bovine trypanosomiasis in Dara district Sidama zone, southern Ethiopia. J Parasitol Vector Biol. 2017; 9: 132-136.

44. Yigzaw B, Asmare T, Derso S. Prevalence of bovine trypanosomiasis and its vector density in Sheka zone, Anderacha woreda. Online J Anim Feed Res. 2017; 7: 51-57.

45. Bakele D, Desta T. Prevalence of bovine trypanosomosis and Apparent Density of tsetse flies in Nonno District, Western Shewa zone, West Ethiopia. J Vet Med Sci. 2019; 1: 7-13.

46. Madalcho EB. A study on the prevalence of bovine Trypanosomiasis and its associated risk factors in Tarcha Zuria District, Dawuro Zone Southern Ethiopia. Int J Res Stud Biosci. 2019; 7: 4-10.

47. Takele E, GecherE G. A study on prevalence of trypanosomosis, its risk factors, and anaemia in cattle of Damot Woyde district, southern Ethiopia. ARC J Anim Vet Sci. 2019; 5: 1-8.

48. Abdeta D, Kebede N, Giday M, Terefe G, Abay SM. In Vitro and In Vivo Antitrypanosomal Activities of Methanol Extract of Echinops kebericho Roots. Evid Based Complement Alternat Med. 2020; 2020: 8146756.

49. Lelisa K, Meharenet B. Anemia associated with trypanosomes infections in cattle of West Gojjam Zone, Northwest Ethiopia. Vet Med Int. 2021; 2021: 5531537.

50. Tsegaye G, Abebe B, Haile G. Prevalence of Bovine Trypanosomosis and Its Associated Risk Factor in Hawa Galan District, Kelem Wollega Zone of Ethiopia. Vet Med Int. 2021; 2021: 4531586.

51. Desta T, Lelisa K. Trypanosomosis and Apparent Densities of Glossina Species in Bilo Nopha District, Southwestern Ethiopia. Europ J Appl Sci. 2018; 10: 43-47.

52. Lemu M, Bekuma F, Abera D, Meharenet B. Prevalence of bovine trypanosomosis and apparent density of tsetse fly in Botor Tolay District, Jimma Zone, Ethiopia. Biomed J Sci Tech Res. 2019; 13: 8.

53. Ramirez AIR. Antigen discovery in Trypanosoma vivax, The University of Liverpool (United Kingdom). 2020.

54. Bett B, Kiunga P, GachohI J, Sindato C, Mbotha D, Robinson T, et al. Effects of climate change on the occurrence and distribution of livestock diseases. Prev Vet Med. 2017; 137: 119-129.

55. Eshetu E, Begejo B. The current situation and diagnostic approach of Nagana in Africa: a review. J Nat Sci Res. 2015; 5: 117-125.

56. Paguem A, Abanda B, Ndjonka D, Weber JS, Ngomtcho SCH, Manchang KT, et al. Widespread co-endemicity of Trypanosoma species infecting cattle in the Sudano-Sahelian and Guinea Savannah zones of Cameroon. BMC Vet Res. 2019; 15: 344.

57. Attanasio G, Covelli E, De Carlo AF, Ilipo R. Cite this article as–. International journal of ayurveda and alternative medicine. 2019; 7.

58. Chiweshe SM, Steketee PC, Jayaraman S, Paxton E, Neophytou K, Erasmus H, et al. Parasite-specific 7SL-derived small RNA is an effective target for the diagnosis of active trypanosomiasis infection. PLoS Negl Trop Dis. 2019; 13: e0007189.

59. Beltrame A, Guerriero M, Angheben A, Gobbi F, Requena-mendez A, Zammarchi L, et al. Accuracy of parasitological and immunological tests for the screening of human schistosomiasis in immigrants and refugees from African countries: An approach with Latent Class Analysis. PLoS Negl Trop Dis. 2017; 11: e0005593.

60. Deng MH, Zhong LY, Kamolnetr O, Limpanont Y, Lv ZY. Detection of helminths by loop-mediated isothermal amplification assay: a review of updated technology and future outlook. Infect Dis Poverty. 2019; 8: 20.

61. Katsanevakis S, Weber A, Pipitone C, Leopold M, Cronin M, Scheidat M, et al. Monitoring marine populations and communities: methods dealing with imperfect detectability. Aqua Biol. 2012; 16: 31-52.

62. Momčilović S, Cantacessi C, Arsić-Arsenijević V, Otranto D, Tasić-otašević S. Rapid diagnosis of parasitic diseases: current scenario and future needs. Clin Microbiol Infect. 2019; 25: 290-309.

63. Carnes J, Anupama A, Balmer O, Jackson A, Lewis M, Brown R, et al. Genome and phylogenetic analyses of Trypanosoma evansi reveal extensive similarity to T. brucei and multiple independent origins for dyskinetoplasty. PLoS Negl Trop Dis. 2015; 9: e3404.

64. Boulangé A, Pillay D, Chevtzoff C, Biteau N, De Graça VC, Rempeters L, et al. Development of a rapid antibody test for point-of-care diagnosis of animal African trypanosomosis. Vet Parasitol. 2017; 233: 32-38.

65. Arnold BF, Scobie HM, Priest JW, Lammie PJ. Integrated serologic surveillance of population immunity and disease transmission. Emerg Infect Dis. 2018; 24, 1188.

66. Fidelis OL, Sampaio PH, Gonçalves LR, André MR, Machado RZ, Wijffels G, et al. Comparison of conventional and molecular techniques for Trypanosoma vivax diagnosis in experimentally infected cattle. Rev Bras Parasitol Vet. 2019; 28: 203-209.

67. Tounkara M, Boulangé A, Thonnus M, Bringaud F, Bélem AMG, Bengaly Z, et al. Novel protein candidates for serodiagnosis of African animal trypanosomosis: Evaluation of the diagnostic potential of lysophospholipase and glycerol kinase from Trypanosoma brucei. PLoS Negl Trop Dis. 2021; 15: e0009985.

68. Richard Gashururu S, Maingi N, Githigia SM, Gasana MN, Odhiambo PO, Getange DO, et al. Occurrence, diversity, and distribution of Trypanosoma infections in cattle around the Akagera National Park, Rwanda. PLoS Negl Trop Dis. 2021; 15: e0009929.

69. Schneider-Crease I, Griffin RH, Gomery MA, Dorny P, Noh JC, Handali S, et al. Identifying wildlife reservoirs of neglected taeniid tapeworms: Non-invasive diagnosis of endemic Taenia serialis infection in a wild primate population. PLoS Negl Trop Dis. 2017; 11: e0005709.

70. Maharana BR, Tewari AK, Saravanan BC, Sudhakar NR. Important hemoprotozoan diseases of livestock: Challenges in current diagnostics and therapeutics: An update. Vet World. 2016; 9: 487-95.

71. Eleizalde M, Gómez-piñeres E, Ramírez-iglesias J, Mendoza M. Evaluation of five primer sets for molecular detection of Trypanosoma vivax by polymerase chain reaction (PCR) and their implementation for diagnosis in naturally infected ruminants from Venezuela. Vet Parasitol Reg Stud Reports. 2021; 25: 100594.

72. Cossic BG, Adjahoutonon B, Gloaguen P, Dibanganga GL, Maganga G, Leroy P, et al. Trypanosomiasis challenge estimation using the diminazene aceturate (Berenil) index in Zebu in Gabon. Trop Anim Health Prod. 2017; 49: 619-624.

73. Chaudhry U, Ali Q, Rashid I, Shabbir MZ, Ijaz M, Abbas M, et al. Development of a deep amplicon sequencing method to determine the species composition of piroplasm haemoprotozoa. Ticks Tick Borne Dis. 2019; 10: 101276.

74. Giordani F, Morrison LJ, Rowan TG, de Koning HP, Barrett MP. The animal Trypanosomiasis and their chemotherapy: a review. Parasitol. 2016; 143: 1862-1889.

75. Yasein G, Zahid O, Minter E, Ashraf K, Rashid I, Shabbir MZ, et al. A novel metabarcoded deep amplicon sequencing tool for disease surveillance and determining the species composition of Trypanosoma in cattle and other farm animals. Acta Trop. 2022; 230: 106416.

76. Dagnachew S, Bezie M, Goddeeris BM. Molecular Diagnosis of Trypanosoma vivax Infections. Global J Mol Sci. 2015; 10: 1-9.

77. Kassian NE. Prevalence and risk factors associated with Trypanosomosis in Cattle Herds in Kilwa District of Lindi Region of Tanzania. University of Zambia. 2015.

78. Bastos TSA, Faria AM, De Assis Cavalcante AS, De carvalho madrid DM, Zapa DMB, Nicaretta JE, et al. Comparison of therapeutic efficacy of different drugs against Trypanosoma vivax on experimentally infected cattle. Prev Vet Med. 2020; 181: 105040.

79. Hemadri D, Suresh K, Patil S, Siju S, Nagalingam M. AICRP on Animal Disease Monitoring and Surveillance Annual Report. 2017-18.

80. Denbarga Y, Ando O, Abebe R. Trypanosoma species causing bovine trypanosomosis in south Achefer District, Northern Ethiopia. J Vet Adv. 2012; 2: 108-113.

81. Gelberg HB. Alimentary system and the peritoneum, omentum, mesentery, and peritoneal cavity. Pathol Basis Vet Dis. 2017; 324-411.

82. Kimaro EG, Abiola PM. Epidemiology and Economic Importance of African Animal Trypanosomiasis. Combating and Controlling Nagana and Tick-Borne Diseases in Livestock. 2021; 24-52.

83. Radwanska M, Vereecke N, Deleeuw V, Pinto J, Magez S. Salivarian trypanosomosis: a review of parasites involved, their global distribution and their interaction with the innate and adaptive mammalian host immune system. Front Immunol. 2018; 9: 2253.

84. Cecilia H, Arnoux S, Picault S, Dicko A, Seck MT, Sall B, et al. Environmental heterogeneity drives tsetse fly population dynamics and control. BioRxiv. 2019.

85. LI M, Yang T, Bui M, Gamez S, Wise T, Kandul NP, et al. Suppressing mosquito populations with precision-guided sterile males. Nat Commun. 2021; 12: 5374.

86. Holt H, Selby R, Mumba C, Napier G, Guitian J. Assessment of animal African Trypanosomiasis (AAT) vulnerability in cattle-owning communities of sub-Saharan Africa. Parasit Vectors. 2016; 9: 53.

87. Feldmann U, Leak SG, Hendrichs J. Assessing the feasibility of creating tsetse and trypanosomosis-free zones. Int J Trop Insect Sci. 2018; 38: 77-92.