Heliyon 7 (2021) e06667

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

# Seasonal prevalence of trypanosomosis, Glossina density and infection along the escarpment of Omo River, Loma district, southern Ethiopia

Tadesse Eyasu [a], Solomon Mekuria [b], Desie Sheferaw [b,*]

[b] Hawassa University Faculty of Veterinary Medicine, Ethiopia
[a] MoLF, Wolaita Zone, Southern Region, Ethiopia

ARTICLE INFO

*Keywords:*
Ethiopia
Glossina
Loma
Omo river
Season
Trypanosome

ABSTRACT

*Background:* The temporal information of trypanosomosis and tsetse apparent density is very limited in the southern part of the country. So, the study was conducted to estimate the temporal, dry and wet seasons, prevalence of cattle trypanosomosis, and tsetse fly apparent density and its infection by trypanosome along the escarpment of Omo River, Loma district, Southern Ethiopia.

*Methods:* A total of 964 cattle (482 in each seasons) were examined for trypanosomosis using buffy coat technique. For Glossina and biting flies study a total of 80 odor-baited, acetone and aged cow urine, NGU traps were deployed around the watering and grazing areas.

*Results:* The overall prevalence of cattle trypanosomosis was 4.98% of which 3.1% and 6.8% accounted to dry and wet seasons, respectively. The prevalence of trypanosomosis was significantly higher during wet season (OR = 1.93, $P < 0.05$), in poor body condition (OR = 3.71, $P < 0.05$) and in black coat colour (OR = 13.18, $P < 0.05$) animals. Two species of Trypanosome, *T. congolense* and *T. vivax*, were circulating in the area both in dry and wet seasons. A total of 327 Glossina (126 *G. pallidipes* and 201 *G. fuscipes*) were traped by using odour baited 80 NGU traps. The overall apparent density of Glossina was 4.1 Flies/Trap/Day. Relatively higher Glossina/Trap/Day caught in wet season (4.9 Flies/Trap/Day) than dry season (3.3 Flies/Trap/Day). Two species of *Glossina* namely *G. pallidipes* and *G. fuscipes* were distributed in the study areas. From the flies caught 127 Glossina were randomly selected and dissected. The overall proportion of Glossina infection was 15% with higher proportion of infection in wet season (19.6%) than the dry season (11.3%). Higher infection proportion was observed in *G. pallidipes*.

*Conclusion:* Trypansomosis is the major challenge for cattle productivity in the district. So to reduce the impact trypanosomosis and Glossina active community participation can play a key role.

## 1. Introduction

Animal trypanosomosis is a lethal parasitic disease caused by unicellular protozoal organisms known as trypanosoma. Trypanosomes are flagellated protozoa that inhabit the extracellular compartment of host blood; and transmitted to mammals by blood sucking flies of the genus Glossina, commonly known as tsetse flies (Itard, 1989; Leak, 1999; Black and Seed, 2002). Trypanosomosis negatively impacted Africa's struggle against poverty; and it is endemic in more than thirty countries (Shallow, 2000). The major clinical manifestation of cattle trypanosomosis are intermittent fever, anaemia, dullness, anorexia, apathetic, watery occular discharge and superficial lymph nodes enlargement. The animals progressively become emaciated and cachectic, and die. In cows, irregular estrous cycle and abortion observed (Constable et al., 2017). Probably more than any other disease affecting livestock, trypanosomosis constrains agricultural production and causes food insecurity in vast and fertile swaths of sub-Saharan Africa (Holt et al., 2016).

In Ethiopia, animal trypanosomosis is widely distributed across the tsetse infested belts, which is found in Sub-Sharan Africa. In these regions, about 220,000 $Km^2$ of fertile land is infested by *Glossina* spp. (Cecchi et al., 2008). In Ethiopia, about five *Glossina* spp. were reported: *G. pallidipes*, *G. morsitans submorsitans*, *G. fuscipes fuscipes*, *G. tachinoides* and *G. longipennis*. The most commonly reported and important *Trypanosoma* spp. affecting cattle in southern and south-western part of the country include *T. congolense*, *T. vivax* and *T. brucei* (Duguma et al., 2015; Abebe, 2005). Cattle production plays a key role in the livelihood of southern and western regions of Ethiopia; however, their production potential is not fully utilized due to endemic diseases like trypanosomosis

* Corresponding author.
*E-mail address:* mereba480@gmail.com (D. Sheferaw).

https://doi.org/10.1016/j.heliyon.2021.e06667
Received 2 January 2021; Received in revised form 10 February 2021; Accepted 29 March 2021

(Abebe, 2005). Trypanosomosis is threatening the agricultural production and cattle breeding more severely than any other livestock disease (Moti et al., 2015).

Information on temporal and spatial dynamics of tsetse and trypanosomes remain limited and may be a reason that control strategies are less effective (Nnko et al., 2017). So knowledge of temporal, dry and wet season, prevalence of trypanosomosis and distribution of tsetse fly are important when devising appropriate strategies for the control of these problems (Van den Bossche and de Deken, 2002). The temporal information of trypanosomosis and tsetse apparent density is very limited in the southern part of the country. Therefore, this study was conducted to estimate the temporal, dry and wet season, prevalence of bovine trypanosomosis, to assess tsetse fly apparent density and its infection by trypanosome.

## 2. Materials and methods

### 2.1. Study area and animals

This study was done along the escarpment of Omo River, Loma district, southern Ethiopia. It is located along the Omo tsetse belt, and has an altitude 501–3300 m.a.s.l. that is located in south western Ethiopia. Geographically, the district is found between 6°34′120″ to 7°6′360″ North and 36°55′480″ to 37°26′240″ East. The district is bordered on the south by Goffa Zone, on the west by Isara district, on the northwest by Maraka district, on the north by Gena Bosa district and on the east by the Wolaita Zone on the eastern and Omo River (Figure 1). The study area characterized by bimodal type of rainfall, the short rainy season (March to May) and the long (June to September). The annual rainfall and temperature of the area is ranged from 900 to 1800 mm and 14–30 °C, respectively (LDAR, 2018). From the district, the four study kebeles were selected purposively based on the level of complaint by animal owners about trypanosomosis. The selected four kebeles were Zima Waruma, Afuki Weyiro, Subo Tulama and Danaba Bolla, which are bordered by Omo river.

The study animals were local breed zebu cattle above six months of age, which were kept by extensive management system. In the area, all animals above six months of age were left for free grazing; and hence, included into the study.

### 2.2. Study design, sample size and sampling

The study was conducted to estimate the seasonal prevalence of trypanosomosis and the apparent density of *Glossina* species and other blood sucking flies; moreover, to assess tsetse flies infection rate by trypanosome. This study was conducted from December 2018 to September 2019 that include dry (December to February) and wet (June August) season.

Repeated cross-sectional study design was employed to estimate the prevalence of trypanosomosis and to identify the *Glossina* species prevailing in the area both in dry and wet seasons. The sample size required for the study was computed by considering trypanosomosis prevalence of 26.8% reported by Teklebirhan et al. (2016), 95% confidence interval and 5% absolute precision. Then to improve the precision the sample size was increased by about 60%. So, a total of 964 animals selected for the study both in dry and wet season. Systematic random sampling technique as described by employed to select the study animals (Thrusfield, 2018). Potential risk factors considered in the study were season, body condition, sex, age and coat colour.

### 2.3. Study methodology

#### 2.3.1. Parasitological study

The marginal ear-veins was punctured with blood-lancet, and then blood samples were collected by heparinized microhaematocrit tubes; and then after, sealed on one side with cristaseal (Hawksley Ltd., Lancing, UK). The microhaematocrit tubes, about three quarters blood filled, were transferred to a haematocrit centrifuge, and centrifuged for 5 min at 1200 revolutions per minute. After that packed cell volume (PCV) was measured by using haematocrit reader. It was then cut at about 1 mm below the buffy-coat and the contents of the tube expressed onto a microscopic slide, mixed and covered with 22 × 22 mm cover slip. Finally, it was examined under 40x and/or 10x objective lens for the presence of motile trypanosomes (Woo, 1969; Murray et al., 1983; Uilenberg 1998); and trypanosome species were identified based on their movement pattern during the buffy coat examination as described by Murray et al. (1977) and Murray et al. (1983).

#### 2.3.2. Entomological studies

Entomological study was conducted from December 2018–January, 2019 and June–August, 2019, which is dry and wet seasons, respectively. A total of 80 odor-baited, acetone and aged cow urine, NGU traps were deployed around the watering and grazing areas closer to trees and bush, which were commonly visited by animals. All the traps were deployed at an altitude of 687 to 1352 masl and at about 200–250m intervals for 48 h. Then after, the flies were collected from the traps and counted, and sex and *Glossina* species were identified following the standard procedure (Uilenberg, 1998; Pollock, 1982). The flies were sorted into teneral and non-teneral; and then the teneral tsetse flies were subjected to dissection and examination for infection with trypanosome as described by Pollock (1982). Other caught biting flies were identified at genera level according to their morphological characteristics such as size, color, wing venation structure and proboscis (Wall and Shearer, 1997).

### 2.4. Data analysis

Collected data were entered into Microsoft Excel spread sheet, coded and summarized by descriptive statistics. The prevalence of trypanosomosis was calculated as the number of infected cattle divided by the total number of sampled animals and then multiplied by 100 (Thrusfield, 2018). The association between the risk factors and infection of trypanosome were analysed with univariable logistic regression. Those risk factors with $p < 0.25$ values were further subjected to multivariable analysis. Tsetse flies infection rate was determined as the number of flies having trypanosomes in the gut, proboscis and salivary gland divided by the total number of non-teneral flies multiplied by 100. The apparent tsetse density (AD) was expressed as the number of flies per traps per day (FTD).

## 3. Results

### 3.1. Trypanosomosis prevalence

Of the total 964 cattle (i.e. 482 in the dry and 482 in the wet seasons) examined by buffy coat technique 48 (4.98%) animals were found positive for trypanosome infection. The prevalence of trypanosome infection in dry and wet season was shown by Figure 2.

Univariable and multivariable logistic regression analysis results of potential risk factors considered for the occurrence of trypanosomosis in this study were shown in Table 1. After the risk factors analysis with univariable logistic analysis those variables with $p < 0.25$ were further subjected to multivariable analysis.

### 3.2. Trypanosome species identified

Two species of *Trypanosomes* were identified, which in order of abundance we *Trypanosoma congolense* (77.1%) and *Trypanosoma vivax* (20.8%). About 2.1% of the animals were infected by mixed *Trypanosome* species, *T. congolense* and *T. vivax*. Seasonally identified Trypanosoma species were shown in Table 2.

### 3.3. Hematological findings

The overall mean PCV value of all studied animals was 25.5% (95% CI = 25.2–25.7); and the detail result shown in Table 3.

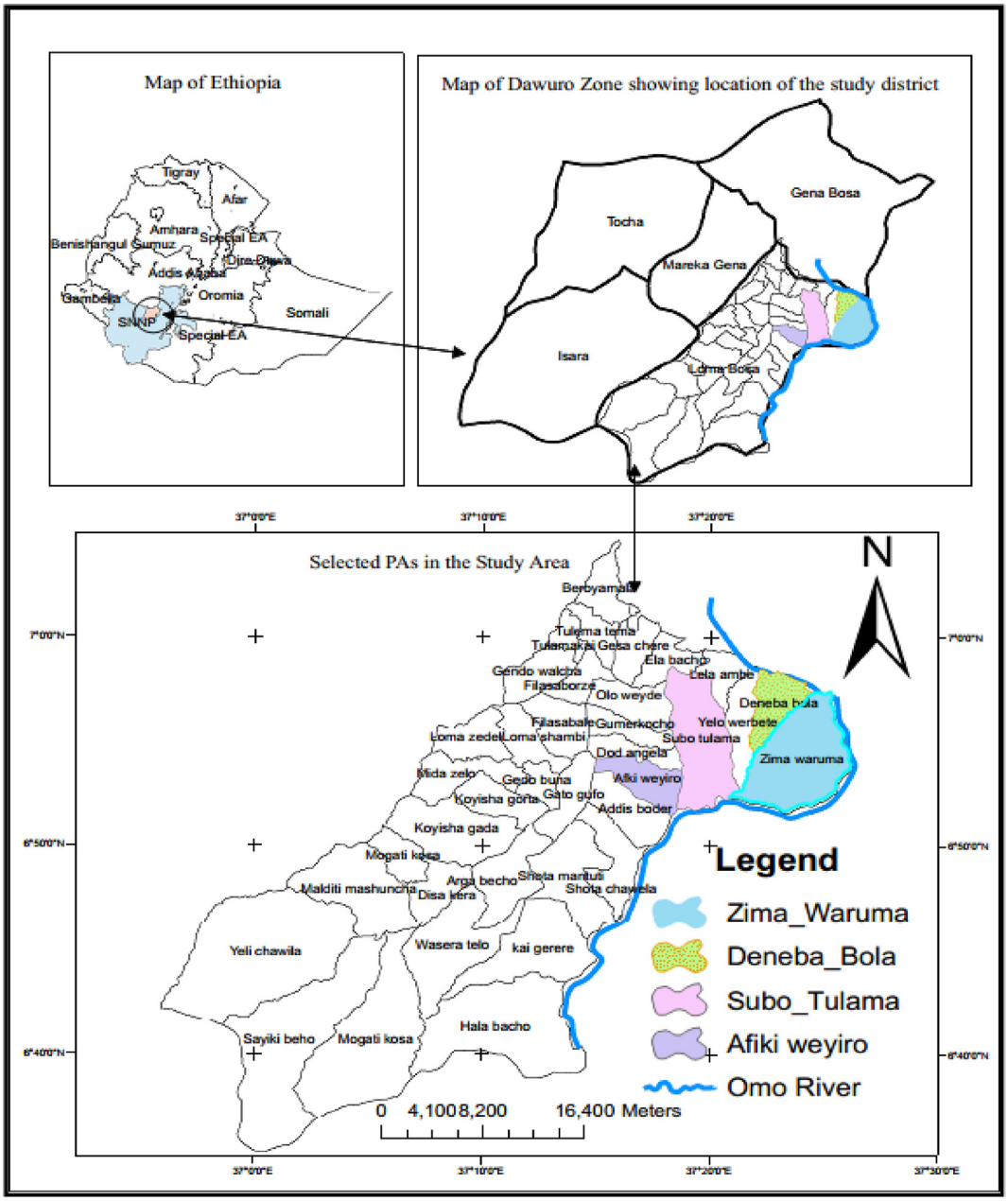


**Figure 1.** Map to show the study area.

### 3.4. Entomological results

A total of 327 *Glossina* species and 607 biting flies were caught with 80 NGU traps deployed in the study areas. The overall apparent density of Glossina species and biting flies were 2.04 F/T/D and 3.79 F/T/D, respectively (Table 4). Both in wet and dry season, two species of Glossina were identified, namely: *Glossina pallidipes* and *Glossina fuscjpes*. The sex proportion of *Glossina pallidipes* was 27% male and 73% female, and that of *Glossina fuscjpes* was 31.8% male and 68.2% female. The biting flies that commonly encountered were *Stomoxys* species (72.2%) and *Tabanus* species (27.8%).

### 3.5. Glossina species infection by trypanosme

From 327 *Glossina* species caught 127 fresh and live flies were dissected; and an overall of 15% (19/127) *Glossina* species was infected by trypanosome. The highest infection rate was found in *G. pallidipes* 23.5% and the lowest was in *G. fuscipes* 11.8% (Table 5).

## 4. Discussion

The overall prevalence of trypanosomosis in the study area was 4.98 %. This finding was in a general agreement with the previous reports from the surrounding areas by Teka et al. (2012) and Fayisa et al. (2015) who found 4.43% and 4.86%, respectively. The prevalence of bovine trypanosomosis in southern part of the country was ranging from 1.3% to 29.5% (Girma et al., 2014; Muktar et al., 2016), using the buffy coat methods. The multivariable analysis revealed that significantly higher prevalence was recorded in wet season ($p < 0.05$, OR = 2.29), poor body condition ($p < 0.05$, OR = 3.84) and black animals ($p < 0.05$, OR = 12.46). Though, trypanosomosis is a wasting disease, which result in a progressive condition loss (Steverding, 2008) and poor body condition is not only due to trypanosomosis. Indeed, the body condition of infected animals affected by the level of protein intake. Black coat colour animals more affected by trypanosomosis than the other colour considered in this study as also reported by Sheferaw et al. (2016) and Abebe et al. (2017). As described by Leak (1999) black materials are attracting *Glossina*

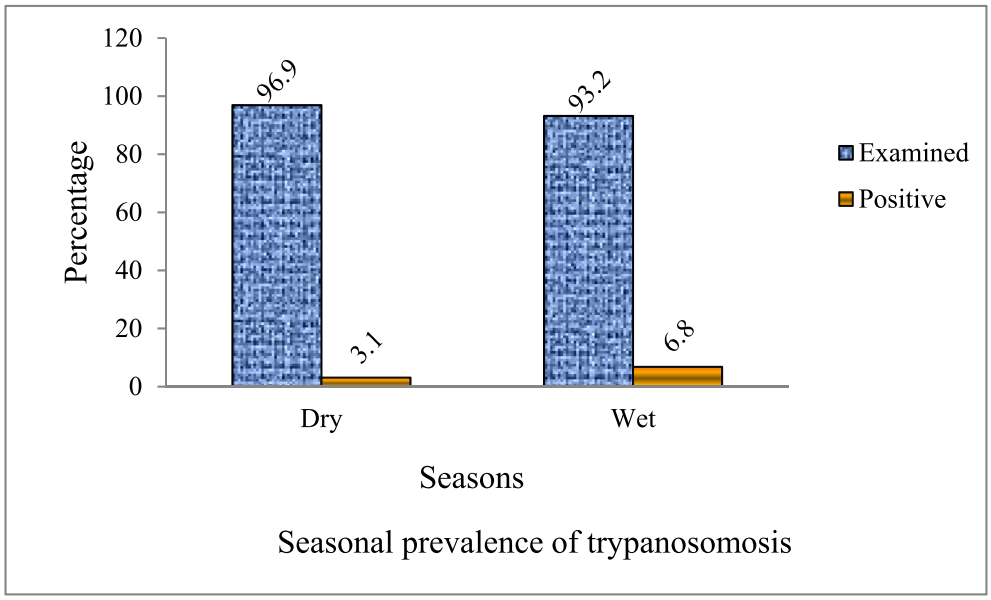


**Figure 2.** Seasonal prevalence of trypanosomosis.

**Table 1.** Univariable and multivariable logistic regression analysis of potential risk factors trypanosomosis.

| Risk factors | Factors level | No examine | No positive (%) | 95% CI | Univariable | | | Multivariable | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | OR | 95% CI | P-value | OR | 95% CI | P-value |
| Season | Dry | 482 | 15 (3.11) | 1.88–5.10 | Ref | - | - | Ref | - | - |
| | Wet | 482 | 33 (6.85) | 4.90–9.48 | 2.29 | 1.23–4.27 | 0.009 | 1.93 | 1.01–3.71 | 0.048 |
| Sex | Female | 636 | 29 (4.56) | 3.18–6.49 | Ref | - | - | - | - | - |
| | Male | 328 | 19 (5.79) | 3.72–8.91 | 1.29 | 0.71–2.33 | 0.405 | - | - | - |
| Age | Young | 254 | 11 (4.33) | 2.41–7.66 | Ref | - | - | - | - | - |
| | Adult | 710 | 37 (5.21) | 3.80–7.11 | 1.22 | 0.61–2.42 | 0.580 | - | - | - |
| BCS | Good | 136 | 3 (2.21) | 0.71–6.65 | Ref | - | - | Refe | - | - |
| | Medium | 552 | 23 (4.17) | 2.78–6.20 | 1.93 | 0.57–6.52 | 0.291 | 1. 93 | 0.57–6.52 | 0.217 |
| | Poor | 276 | 22 (7.79) | 5.30–11.82 | 3.84 | 1.13–13.06 | 0.031 | 3.84 | 1.13–13.06 | 0.040 |
| Color | White | 91 | 2 (2.20) | 0.55–8.44 | Ref | - | - | Ref | - | - |
| | Roan | 643 | 25 (3.89) | 2.53–5.48 | 1.73 | 0.40–7.43 | 0.461 | 1.69 | 0.39–7.29 | 0.483 |
| | Gray | 173 | 14 (8.09) | 4.84–13.23 | 3.92 | 0.87–17.63 | 0.075 | 3.68 | 0.81–16.71 | 0.091 |
| | Black | 32 | 7 (21.88) | 10.66–39.64 | 12.46 | 2.43–63.79 | 0.002 | 13.18 | 2.53–68.66 | 0.002 |
| Total | | 964 | 48 (4.98) | 3.69–6.55 | - | - | - | - | - | - |

**Table 2.** Proportion of *Trypanosome* species identified in dry and wet season (n = 48).

| Season | *T. congolense* (%) | *T. vivax* (%) | Mixed (%) | Overall (%) | Overall 95% CI |
|---|---|---|---|---|---|
| Dry | 9 (18.8) | 6 (12.5) | - | 15 (31.3) | 15.6–46.7 |
| Wet | 28 (58.3) | 4 (8.3) | 1 (2.1) | 33 (68.7) | 49.0–94.9 |
| Total | 37 (77.1) | 10 (20.1) | 1 (2.1) | | |

**Table 3.** Analysis of the association of trypanosome infections with mean PCV (%) of cattle.

| Factors | No examined | Mean PCV | Std. Dev | 95% CI | t-test | P-value |
|---|---|---|---|---|---|---|
| Trypanosome | | | | | | |
| Non-infected | 916 | 25.6 | 4.18 | 25.3–25.9 | | |
| Infected | 48 | 23.0 | 2.92 | 22.1–23.8 | 4.31 | 0.000 |
| Season | | | | | | |
| Dry | 482 | 24. 6 | 4.20 | 24.2–24.9 | | |
| Wet | 482 | 26.4 | 3.93 | 26.0–26.7 | 6.86 | 0.000 |
| Overall | 964 | 25.5 | 4.16 | 25.2–25.7 | | |

**Table 4.** Summary of the seasonal AD of major fly vectors trapped in the study period.

| Season | Traps deployed | Glossina species and F/T/D | | | Biting flies (AD) |
|---|---|---|---|---|---|
| | | *G. pallidipes* | *G. fuscipes* | Total | |
| Dry | 40 | 56 (1.4) | 75 (1.9) | 131 (3.3) | 14 (0.4) |
| Wet | 40 | 70 (1.8) | 126 (3.2) | 196 (4.9) | 593 (14.8) |
| Overall | 80 | 126 (1.6) | 201 (2.5) | 327 (4.1) | 607 (7.6) |

AD = Apparent Density.

**Table 5.** Seasonal infection rate of *Glossina* species by trypanosome.

| Glossina species | Dissection and infection rate | | | | | |
|---|---|---|---|---|---|---|
| | Dry season | | Wet season | | Overall | |
| | No dissected | No infected (%) | No dissected | No infected (%) | No dissected | No infected (%) |
| *G. pallidipes* | 16 | 5 (31.3) | 18 | 3 (16.7) | 34 | 8 (23.5) |
| *G. fuscipes* | 40 | 6 (15.0) | 53 | 5 (9.4) | 93 | 11 (11.8) |
| Total | 56 | 11 (19.6) | 71 | 8 (11.3) | 127 | 19 (15.0) |

species; and this may increase the chance of black coat coloured animals to be bitten by the flies and facilitate the transmission of trypanosoma.

The relatively higher prevalence of *T. congolense* observed in this study confirms the observation of Gona et al. (2016), Abebe et al. (2017), Tesfaye and Basa (2017) and Eshetu et al. (2017). Various reports (Gona et al., 2016; Abebe et al., 2017; Tesfaye and Basa, 2017; Eshetu et al., 2017) revealed that *T. congolense* is more prevalent in areas where *G. pallidipes* is the predominating species.

The overall mean PCV of all the studied animals was 25.5%. The mean PCV (23%) of infected animals, both in wet (23.6%, $t = 4.24$, $P < 0.05$) and dry period (21.5%, $t = 2.86$, $P < 0.05$), were significantly higher ($t = 6.86$, $P < 0.05$) than the non-infected. So, infected animals under any level of diet characterized by drop in PCV (Holmes et al., 2000). But the level of nutrition ans season of infection affect the time of recovery from anaemia, which means rapid in wet season than the dry season (Agyemang et al., 1990). Because nutritional deficiencies reduce PCV (Van den Bossche and Rowlands, 2001). Although, trypanosomosis is characterized by reduced in PCV, it should be known that other factors like parasitism and nutritional deficiencies also causes for lowering PCV.

Two species of *Glossina* were identified, namely: Glossina pallidipes and Glossina fuscipe. These species were also reported by various authors from areas neighbouring to the study district in a different period (Asha et al., 2008; Sheferaw et al., 2016; Abebe et al., 2017). The total *Glossina* species caught in wet period was 4.9 Glossina/T/D, which is higher than the dry period 3.3 Glossina/T/D. This is an indication for seasonal variation of Glossina distribution that is relatively higher apparent density observed in wet season (Desta et al., 2013; Majekodunmi et al., 2013; Ouma et al., 2006; Van den Bossche and de Deken, 2002). The decline in the invasion of Glossina species might be due to increasing of mortalities as well as the increasing of the rate of reproductive abnormality during dry season (Torr and Hargrove, 1999). A positive relationship was observed between trypanosome prevalence and the *Glossina* species apparent density, which implies the higher *Glossina* species apparent density the higher prevalence of trypanosomosis (Majekodunmi et al., 2013).

From a total of 125 *Glossina* species dissected 19 (15%) flies were infected by trypanosome species. Overall, higher proportions of *G. pallidipes* (23.5%) were infected than *G. fuscipes* (11.8%), which is also true both in dry (i.e. 31.3% for *G. pallidipes* and 15% for *G. fuscipes*) and wet (16.7% for *G. pallidipes* and 9.4% for *G. fuscipes*) seasons. flies was relatively higher during the dry period; and higher infection percentage was recorded in than in. This finding is in a general agreement with the report of Majekodunmi et al. (2013) and Bitew et al. (2011). According to this author an increasing in the proportion of Glossina infection was followed by increased prevalence of trypanosomosis.

## 5. Conclusion

The overall prevalence of trypanosomosis in cattle was 4.98%, and the seasonce prevalences were 3.1% and 6.8% in dry and wet seasons, respectively. Two species of trypanosoma were circulating in the study area, *T. congolense* and *T. vivax*, with significantly higher *T. congolense* distribution. The prevalence of trypanosomosis was significantly higher in wet season, in poor body condition, and black coat animals. Relatively higher Glossina/Trap/Day caught in wet season than dry season. Two species of *Glossina* namely *G. pallidipes* and *G. fuscipes* were distributed in the study areas. The overall proportion of Glossina infection was 15% with higher proportion of infection in wet season than the dry season. Higher infection proportion was observed in *G. pallidipes*.

## Declarations

### *Author contribution statement*

Tadesse Eyasu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Solomon Mekuria: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Desie Sheferaw: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

### *Funding statement*

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### *Data availability statement*

Data associated with this study has been deposited at Hawassa University website.

### *Declaration of interests statement*

The authors declare no conflict of interest.

### *Additional information*

No additional information is available for this paper.

## Acknowledgements

The authors are grateful to the STEP in Arbaminch and Wolaitasoddo, and the staff members for their great support during the study.

## References

Abebe, G., 2005. Trypanosomosis in Ethiopia, review article. Ethiop. J. Biol. Sci. 4 (1), 75–121.

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

Agyemang, K., Dwinger, R.H., Touray, B.N., Jeannin, P., Fofana, D., Grieve, A.S., 1990. Effects of nutrition on degree of anaemia and liveweight changes in N'Dama cattle infected with trypanosomes. Livest. Prod. Sci. 26 (1), 39–51.

Asha, A., Sheferaw, D., Wossene, A., Fekadu, A., 2008. Prevalence of bovine trypanosomosis and tsetse density inselected woreds of SNNPRS. Ethiop. Vet. J. 12 (2), 131–139.

Bitew, M., Amide, Y., Zenebe, T., Hailu Degefu, H., 2011. Trypanosome infection rate in *Glossina pallidipes* and *Glossina fuscipes* in Gojeb valley, Southwest Ethiopia. Global Vet. 6 (2), 131–135.

Black, S.J., Seed, R.J., 2002. The African Trypanosomes. Kluwer Academic Publisher, New York, Boston, Dordrecht, London, Moscow, p. 179.

Cecchi, G., Mattioli, R.C., Slingenbergh, J., Delarocque, S., 2008. Land cover and tsetse fly distributions in sub-Saharan Africa. Med. Vet. Entomol. 22 (4), 364–373.

Constable, P.D., Hinchcliff, K.W., Done, S.H., Grünberg, W., 2017. Veterinary Medicine: a Textbook of the Diseases of Cattle, Horses, Sheep, Pigs, and Goats, eleventh ed. Elsevier Ltd., 3251 Riverport Lane, St. Louis, Missouri 63043, pp. 2150–2156.

Desta, M.R., Menkir, S., Kebede, A., 2013. Prevalence and seasonal incidence of bovine trypanosomosis in Birbir valley, Baro Akobo River system, Western Ethiopia. J. Vet. Med. Anim. Health 5 (5), 138–143.

Duguma, R., Tasew, S., Olani, A., Damena, D., Alemu, D., Mulatu, T., Alemayehu, Y., Yohannes, M., Bekana, M., Hoppenheit, A., Abatih, E., Habtewold, T., Delespaux, V., Duchateau, L., 2015. Spatial distribution of *Glossina sp.* and *trypanosoma sp.* in south-western Ethiopia. Parasites Vectors 8, 430, 2015.

Eshetu, E., Barata, B., Butako, B., 2017. The prevalence of bovine trypanosomosis and associated risk factors in Mareka Woreda of Dawuro Zone, Southern Ethiopia. J. Parasitol. Vector Biol. 9 (5), 39–46.

Fayisa, G., Mandefro, A., Hailu, B., Chala, G., Alemayehu, G., 2015. Epidemiological status and vector identification of bovine trypanosomiosis in Didesa district of Oromia regional state, Ethiopia. Int. J. Nutr. Food Sci. 4 (3), 373–380.

Girma, K., Meseret, T., Tilahun, Z., Haimanot, D., Firew, L., Tadele, K., Zelalem, A., 2014. Prevalence of bovine trypanosomosis, its vector density and distribution in and around Arba Minch, Gamo Gofa zone, Ethiopia. Acta Parasitologica Globalis 5 (3), 169–176.

Gona, Z., Teshale, A., Tilahun, A., 2016. Study on prevalence of bovine trypanosomosis and density of its vectors in three selected districts of Wolaita Zone, Southern Ethiopia. J. Vet. Med. Anim. Health 8 (9), 128–135.

Holmes, P.H., Katunguka-Rwakishaya, E., Bennison, J.J., Wassink, G.J., Parkins, J.J., 2000. Impact of nutrition on the pathophysiology of bovine trypanosomiasis. Parasitology 120, S73–S85.

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

Itard, J., 1989. African animal trypanosomosis. In: Shah-Fischer, M., Say, R. (Eds.), Manual of Tropical Veterinary Parasitology. CAB International, Wallingford Oxin OX10 8DE, UK, pp. 177–297.

LDAR, 2018. Loma Administrative Annual Report, Loma District Agricultural and Rural Development Office, Gessa, Ethiopia, p. 44.

Leak, S.G.A., 1999. Tsetse Biology and Ecology: Their Role in the Epidemiology and Control of Trypanosomosis. CABI publishing in association with ILRI, Nairobi, Kenya, Wallingford, UK, p. 568.

Majekodunmi, A.O., Fajinmi, A., Dongkum, C., Picozzi, K., MacLeod, E., Thrusfield, M.V., Shaw, A.P.M., Welburn, S.C., 2013. Social factors affecting seasonal variation in bovine trypanosomiasis on the Jos Plateau, Nigeria. Parasites Vectors 6, 293.

Moti, Y., De Deken, R., Thys, E., Van Den Abbeele, J., Duchateau, L., Delespaux, V., 2015. 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. 146, 45–52.

Muktar, Y., Asmelash, M., Mekonnen, N., 2016. Prevalence and associated risk factors of bovine trypanosomosis in Benatsemay district, South Omo zone, Ethiopia. Livest. Res. Rural Dev. 28, 228. Retrieved. http://www.lrrd.org/lrrd28/12/mukt28228.htm. (Accessed 11 December 2020).

Murray, M., Murray, P.K., McIntyre, W.I.M., 1977. An improved parasitological technique for the diagnosis of African trypanosomiasis. Trans. R. Soc. Trop. Med. Hyg. 71 (4), 325–326.

Murray, M., Trail, J.C.M., Turner, D.A., Wissocq, Y., 1983. Livestock Productivity and Trypanotolerance, Network Training Manual. International Livestock Centrefor Africa, Addis Ababa, p. 197.

Nnko, H.J., Ngonyoka, A., Salekwa, L., Estes, A.B., Hudson, P.J., Gwakisa, P.S., Cattadori, I.M., 2017. Seasonal variation of tsetse fly species abundance and prevalence of trypanosomes in the Maasai Steppe, Tanzania. J. Vector Ecol. 42 (1), 24–33.

Ouma, J.O., Marquez, J.G., Krafsur, E.S., 2006. Microgeographical breeding structure of the tsetse fly, Glossina pallidipes in south-western Kenya. Med. Vet. Entomol. 20 (1), 138–149.

Pollock, J.N., 1982. Training manual for tsetse control personnel, Vol. 1, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy, p. 274.

Shallow, B.M., 2000. Impact of Trypanosomosis on African Agriculture, a PAAT Technical and Scientific Series 2. FAO of the United Nation, p. 46.

Sheferaw, D., Birhanub, B., Asrade, B., Abera, M., Tusse, T., Fikadu, A., Denbarga, Y., Gona, Z., Regassa, A., Moje, N., Kussito, E., Mekibib, B., Asefa, T., Woldesenbet, Z., 2016. Bovine trypanosomosis and Glossina distribution in selected areas of southern part of Rift Valley, Ethiopia. Acta Trop. 154, 145–148.

Steverding, D., 2008. The history of African trypanosomiasis: review. Parasites Vectors 1, 3.

Teka, W., Terefe, D., Wondimu, A., 2012. Prevalence study of bovine trypanosomosis and tsetse density in selected villages of Arbaminch, Ethiopia. J. Vet. Med. Anim. Health 4 (3), 36–41.

Teklebirhan, T., Kifleyohannes, T., Tonamo, A., 2016. Prevalence and control of approaches used in tsetse and trypanosomosis of bovine at Loma woreda, Dawuro Zone, Southern Ethiopia. Europ. J. Biol. Sci. 8 (1), 1–7.

Tesfaye, W., Basa, E.B., 2017. Study on prevalence of bovine trypanosomosis and its risk factors in Zala Woreda, SNNPRS, Southern Ethiopia. Int. J. Adv. Res. Biol. Sci. 4 (6), 136–143.

Thrusfield, M., 2018. Veterinary Epidemiology, 4rd ed. Black well Science Ltd, London, pp. 272–293.

Torr, S.J., Hargrove, J.W., 1999. Behaviour of tsetse (Diptera: Glossinidae) during the hot season in Zimbabwe: the interaction of micro-climate and reproductive status. Bull. Entomol. Res. 89, 365–379.

Uilenberg, G., 1998. A Field Guide for the Diagnosis, Treatment and Prevention of African Animal Trypanosomosis. FAO, Rome, Italy, p. 158.

Van den Bossche, P., de Deken, R., 2002. Seasonal variations in the distribution and abundance of the tsetse fly, Glossina morsitans morsitans in eastern Zambia. Med. Vet. Entomol. 16 (2), 170–176.

Van den Bossche, P., Rowlands, G.J., 2001. The relationship between the parasitological prevalence of trypanosomal infections in cattle and herd average packed cell volume. Acta Trop. 78 (2), 163–170.

Wall, R., Shearer, D., 1997. Veterinary Entomology. Arthropod Ectoparasites of Veterinary Importance. Champman and Hall, London, pp. 141–193.

Woo, P.T.K., 1969. The haematocrit centrifuge for the detection of trypanosomes in blood. Can. J. Zool. 47, 921–923.