

Bovine and equine trypanosomosis in Northwest Ethiopia: Prevalence, density of vectors and control measures

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ABSTRACT

A cross-sectional study was carried out from November 2016 to May 2017 in selected districts of Northwest Ethiopia (Jawi, South Achefer, Dembecha and Jabitehenan) with the aim of determining the prevalence of bovine and equine trypanosomosis, estimating the apparent density of vectors and assessing the effectiveness of control measures of the disease. A total of 1257 animals of which 803 bovine and 454 equine were examined for the determination of prevalence using blood sample collected from ear vein of animals. The buffy coat technique was employed to determine the prevalence and the packed cell volume (PCV) value. During sampling animals were categorized into age, body condition score, sex and hair coat color. A total of 40 monoconical traps 10 per district were deployed to estimate the apparent density of vectors. To assess control measures representative number of farmers were interviewed with a prepared questionnaire and using secondary data from veterinary offices. The overall prevalence of trypanosomosis was 7.47% and 4.40% for bovine and equine species, respectively. The prevalence of bovine trypanosomosis was 9.46%, 6.13%, 8.11% and 5.98% while prevalence in equine was 7.8%, 5.3%, 2.7% and 1.8% in Jawi, South Achefer, Dembecha and Jabitehenan districts, respectively. Significance differences in the prevalence of trypanosomosis were observed in hair coat color, age and body condition score in bovine while only body condition was significant in equine. The mean PCV value of parasitemic animals was significantly ($P < .001$) lower than that of aparasitaemic animals. The apparent densities of vectors were 1.04, 0.97, 0.32 fly/trap/day for *Glossina*, *Stomoxys* and *Tabanus* respectively. *Glossina m. submorsitans* and *G. tachinoides* were the species of tsetse identified. The questionnaire response indicated that trypanosomosis was found to be a serious constraint on livestock health in the study areas. The application of continuous trypanosomosis control measures particularly in Jawi and South Achefer districts which were showed an increasing trend in livestock number might be attributed to control effectiveness. In conclusion the presence of trypanosomes and potential vectors necessitate the application of sustainable and integrated control methods in the study areas.

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1. Introduction

Trypanosomosis which is the main haemoparasitic disease in domestic animals and human caused by the protozoan parasite *Trypanosoma* (Holmes, 2013). The parasite is transmitted biologically by the tsetse (*Glossina* species) and mechanically by biting flies (*Stomoxys*, *Tabanus* and *Hematopota*). The 'tsetse belt' region covers an area which extends approximately 10 million km² across 37 countries in sub-Saharan Africa (Parryet et al., 2004; Ilemobade, 2009). In Ethiopia, tsetse transmitted trypanosomosis is arguably the single most important disease, which excludes over 150,000–220,000 km² of fertile land in the Northwest and Southwest of the country from agricultural production (Abebe, 2005; Dagnachew et al., 2017).

In Ethiopia, the disease is economically important and livestock found below 2000 m above sea level (m.a.s.l.) are exposed to various levels of trypanosome risk (Molalegne et al., 2010). As a result, a total of 14.8 million cattle, 6.12 million sheep and goats, 1 million camels and 1.3 million equine are at risk of contracting trypanosomes in Ethiopia (NTTICC, 2000). More than 20,000 heads die per year and annual loss attributed to the disease is estimated to be over US\$ 236 million, whereas losses due to reduce meat, milk and draft power are not computed in this fig. (OAU, 2001). The most important *Trypanosoma* species are *T. congolense*, *T. vivax* and *T. brucei* in cattle, sheep, goats and equines. Camels are affected by *T. evansi* which is the common species in camel rearing areas of the country while equines mainly horses are affected by *T. equiperdum* in some highland parts of the country (Abebe, 2005). Tsetse is widely distributed in the Southwestern and Northwestern low lands and river valleys. Fifteen percent of the land believed to be suitable for livestock production is affected by one or more of the following species of tsetse; *Glossina morsitans morsitans* (*G. m. morsitans*), *Glossina pallidipes* (*G. pallidipes*), *Glossina tachinoides* (*G. tachinoides*), *Glossina fuscipes fuscipes* (*G. f. fuscipes*) and *Glossina longipennis* (*G. longipennis*) (Abebe, 2005). Apart from cyclical transmission of trypanosomosis by *Glossina* species, mechanical transmission is a potential threat to livestock productivity in wide areas of Ethiopia (Abebe and Jobre, 1996). For instance mechanically transmitted *T. vivax* is reported from northwest Ethiopia (Cherenet et al., 2006; Sinshaw et al., 2006).

In western part of Amhara region including West Gojjam, Awi, North Gondar and East Gojjam Zones bordering the Abay river valley is one of the tsetse belt areas of Ethiopia, tsetse transmitted trypanosomosis is becoming a serious threat for livestock production and agricultural activity (Cherenet et al., 2006; Dagnachew et al., 2005). Accordingly tsetse and trypanosomosis control programs have been carried out by the application of pour-on, traps, targets and trypanocidal drugs (NTTICC, 2000). The control practices were implemented two times per year i.e. before and after rainy season. However, the control program is not sustainable due to various challenges encountered during implementation (Cherenet et al., 2006; Dagnachew et al., 2005). As a result tsetse transmitted trypanosomosis threat, a large proportion of the livestock population is forced to reside in tsetse free highland and due to climate changes tsetse expands to previously tsetse free areas. Hence regular assessments of trypanosomosis have a paramount importance to plan and implement evidence based interventions. Therefore, the objectives of this study were to determine prevalence of bovine and equine trypanosomosis, estimate apparent densities of vectors and to assess control measures in the study areas.

2. Materials and methods

2.1. Study areas

The study was conducted in four districts namely Jabitehenan, Dembecha and South Achefer from West Gojjam Zone and Jawi district from Awi Zone of Amhara region (Fig. 1). The districts were selected purposively to include tsetse and trypanosomosis control measures implemented starting from 2000 (NTTICC, 2000). The districts climate alternates with long summer rainfall (June–September) and winter dry season (December–March) with mean annual rain fall of 1200–1600 mm. and mean temperature of 10–20 °C. The altitude ranges from 1100 to 1500, 1400–2300, 1500–2500 and 648–1300 m.a.s.l. for Jabitehenan, Dembecha, South Achefer and Jawi districts respectively. The areas are occupied by savanna grass land, cultivated land, grazing land, bush and woodland, rivers and water bodies and the remaining is engaged by settlement population. The livestock population includes cattle, equines and small ruminants which are an integral part of the livelihood of the people (CSA, 2017).

2.2. Study animals

The study animals include bovine species (Zebu cattle) and equine (donkeys and mules), which were usually kept in an extensive husbandry system. The herd size of farmers living in a village ranged from 30–40 animals which grazed freely during the day and were housed in a common barn at night.

2.3. Study design and methodology

2.3.1. Cross-sectional study

Cross-sectional was conducted from November 2016 to May 2017 to estimate the prevalence of trypanosomosis, measure packed cell volume (PCV) and to determine the apparent density of tsetse and other biting flies.

The study area in Ethiopia

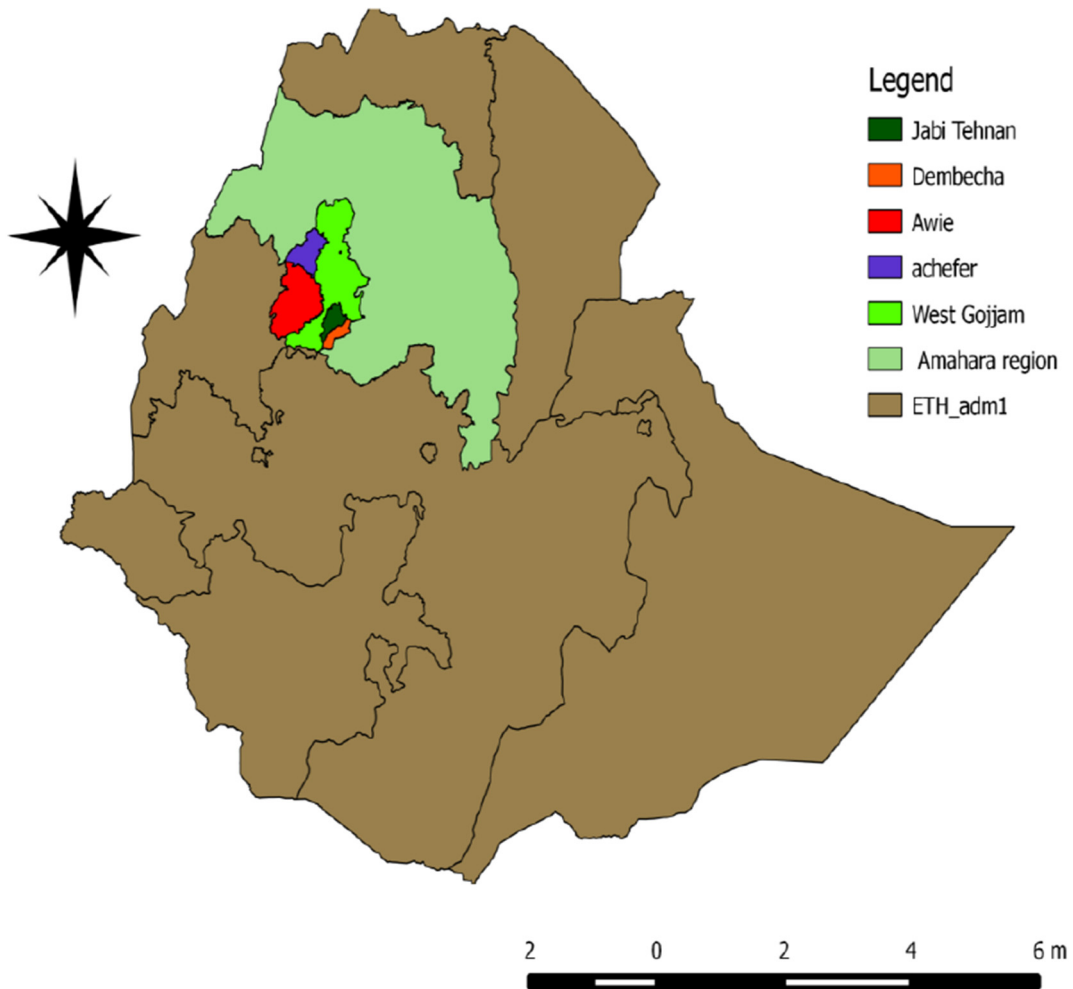


Fig. 1. Map of Ethiopia showing the location of the study areas source (CSA, 2013).

2.3.1.1. Sampling method and sample size determination. Four districts were selected purposively from western Amhara region to represent tsetse infested areas and where control measures have been implemented. From each district Peasant Associations (Kebeles the administrative branches of districts) were selected randomly. The sampling strategy was cluster sampling method and herds were considered as clusters to sample animals from each Kebele. Herd is defined as a group of animals which constitute on average 30–40 animals (cattle and equines) owned by people living together in a village and their animals share the same barn at night and the same grazing area and watering points. Clusters were selected randomly and about 36 herds were required to determine the optimum sample size. Accordingly the sample sizes were determined based on the expected prevalence of 20% for bovine (Dagnachew et al., 2005) and 10.7% for equine (Bedada and Dagnachew, 2012), absolute desired precision of 5% at confidence level of 95%. Consequently a total of 246 bovine and 147 equine were needed to be sampled (Thrusfield, 2005). But in case of cluster sampling the subjects are not independent and hence larger sample is required. Therefore, as rule of thumb triples the numbers of animals required for simple random sample are needed (Martin et al., 1987). Consequently a total of 1257 animals, 803 bovine and 454 equine were used for the study. All equine species (354 donkeys and 20 mules) were adults and males because the areas are not favourable for breeding. Parameters like sex, age, body condition score and color coat of animals were recorded during sample collection. The age of animal was determined by dentition (DeLahunta and Habel, 1986; Caren, 1997) and categorized into adult and young. The body condition score was grouped in to poor, medium and good conditioned animals (Nicholson and Butterworth, 1986; NEWC, National Equine Welfare Council, 2005). The research project was approved by the ethical research review committee of the College of Veterinary Medicine and Animals Sciences of University of Gondar and the owner of the animals were agreed for the objectives of the study and verbal consent were obtained before sampling. Samples from animal were taken by qualified veterinarians.

2.3.1.2. Parasitological and haematological examination. Blood samples were obtained by puncturing of the ear vein with a lancet and collected directly into a haematocrit capillary tubes, sealed one end with 'Cristaseal' (Hawkely) and examined by dark ground buffy coat technique to detect the presence of trypanosomes according to Murray and McIntyre (1977). The capillary tubes were placed in microhaematocrit centrifuge at 12,000 rpm for five minutes. The centrifuged tubes were placed in haematocrit reader where the reading was expressed as a percentage of packed red cells to the total volume of whole blood. Haematocrit tubes were cut by diamond tipped pencil few millimeters below the junction of the buffy coat, the contents homogenized onto clean slide and covered with a 22 × 22 mm cover slip. The slides were examined under a microscope using 40 x magnification for movement of parasite. Thin blood smears stained with Giemsa were made from positive samples (Murray et al., 1982) for species identification. However, the molecular technique which might help species specific identification was not applied because of the limitation in facility and resources.

2.3.1.3. Entomological survey. To assess the apparent density and species of tsetse and other biting flies monoconical type of traps were deployed for 72 h in different vegetation types (savanna grass land, riverine, bush woodland and cultivated land) parallelly with the parasitological study. The traps were baited with acetone and cow urine (Brightwell et al., 1987) which were placed on the ground about 30 cm upwind of the trap. About 40 traps 10 per district were deployed uniformly in each vegetation types of the selected sites. The species and sex of the captured flies were identified based on morphological characteristics (FAO, 2009; Walle and Shearer, 1997). The apparent densities of tsetse and biting flies were determined based on the daily mean number of flies captured and recorded as fly per trap per day (F/T/D) (Leak et al., 1987). However, fly dissection to determine the infection rates of trypanosomes was not done as it requires fresh tsetse for the detection of motile parasites.

2.3.2. Questionnaire survey

A questionnaire survey was conducted to assess the problems of trypanosomosis and the effectiveness of disease control measures implemented in the study areas. A structured questionnaire format was administered on 200 representative farmers, 50 per district. The farmers were selected randomly from owner of animals sampled for the parasitological examination. The amount and types of trypanocidal drug used, practice of treatment in the control of trypanosomosis for the last five consecutive years were assessed from the data record in the veterinary office of each district.

2.4. Data analysis

Data recorded during sample collection includes parasitological examination, PCV measurement, flies caught as well as questionnaire responses and secondary data were entered into Excel Spread Sheets and imported to SPSS version 20 for analysis. Descriptive statistics, student *t*-test and logistic regression were used to explain results and analysis of variables. Trypanosome infection rates with variables of age, sex, body condition score and coat color were compared by using univariate and multivariate logistic regression analysis to determine the strength of the associations. The apparent fly density with variables considered (district, altitude level and vegetation types) were analyzed using Wilcoxon signed ranks test. Student's *t*-test was employed to compare the mean PCV of parasitaemic with that of aparasitaemic animals. Data was checked for normality before comparing means of the variables measured. Descriptive statistics was used for the questionnaire survey. The test result was considered significant at $P < .05$.

3. Results

3.1. Parasitological survey

3.1.1. Trypanosome prevalence

The overall prevalence of bovine and equine trypanosomosis was 7.47% and 4.40%, respectively. The prevalence of bovine trypanosomosis at district level was 9.46%, 6.13%, 8.11%, 5.98% while that for equine was 7.8%, 5.3%, 2.7% and 1.8% in Jawi, South Achefer, Dembecha and Jabitehenan, respectively. Cattle was 1.7 times more likely to be affected by trypanosomosis than equine and the difference (Table 1) was significant ($P = .034$).

Trypanosoma congolense and *T. vivax* were the only trypanosome species identified during the study period (Fig. 2A). *T. congolense* was more prevalent (80%) than *T. vivax* (20%) in bovine species. Similarly *T. congolense* account (95%) compared to *T. vivax* (5%) in equine. From sampled animals severely affected cow with *T. congolense* infection was found (Fig. 2B) during the study period.

Adult cattle were 4.2 times more likely to be affected by trypanosomosis than young cattle. Poor body conditioned animals were 5.8 times more likely to be affected by trypanosomosis than good body conditioned animals while medium body conditioned animals were 1.9 times more likely to be affected by trypanosomosis than good body conditioned animals. Black colored animals were 6.2 times more likely to be affected by trypanosomosis than white colored animals while red colored animals were 1.7 times more likely to be affected by trypanosomosis than white colored animals. The prevalence of bovine trypanosomosis with respect to age, BCS and color coat groups showed a significant difference ($P < .05$) but the difference was insignificant in districts and sex ($P > .05$) categories (Table 2).

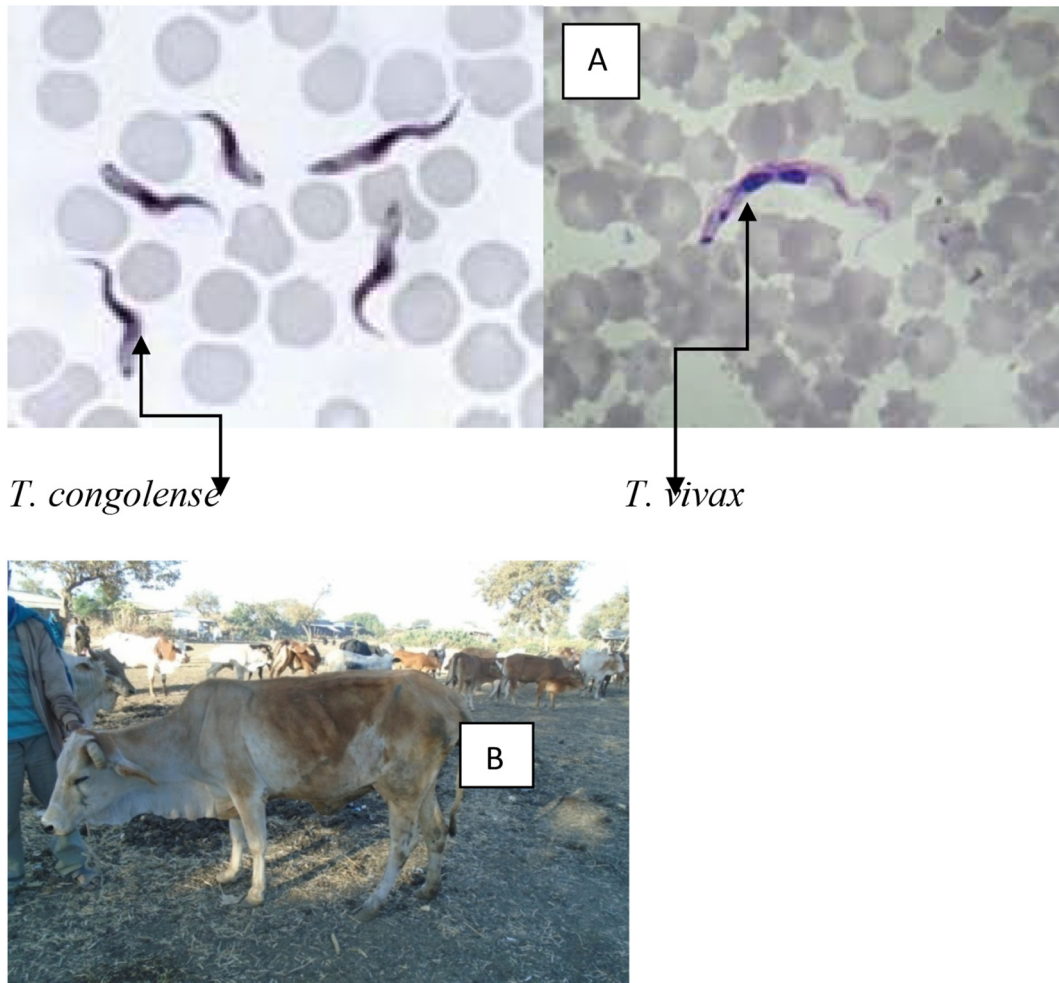
From a total of 454 equines (434 donkeys and 20 mules) examined 20 (4.4%) all donkeys were positive for trypanosome infections. Poor body conditioned equine were 8 times more likely to be affected by trypanosomosis than good body condition

Table 1

Prevalence of bovine and equine trypanosomosis in selected districts of Western Amhara region, Northwest Ethiopia during the study period.

Risk factor	Number examined	Number positive	Prevalence (%)	OR*	95% CI		P-value
					Lower	Upper	
Species							
Equine	454	20	4.40		2.2	6.7	
Bovine	803	60	7.47	1.7	5.8	9.2	0.034

OR*- odds ratio.

**Fig. 2.** A) *T. congolense* and *T. vivax* identified in the study areas using Giemsa stain, B) *T. congolense* positive cattle in Jabitehenan district showed emaciation and weakness.

equine while medium body conditioned equine were 4.7 times more likely to be affected by trypanosomosis than good body conditioned equine. The prevalence of equine trypanosomosis with respect to BCS showed a significant difference ($P < .05$) with poor body condition equine were among medium and good condition animals whilst the prevalence among districts was not significant ($P > .05$) as shown in Table 3. Since the majority of equines were male and adult these parameters were not considered as risk factors of trypanosome infections.

3.1.2. Haematological findings

The PCV value in bovine species ranges from 14 to 46% and the mean PCV value in parasitaemic animals was $20.97 \pm 2.82SD$ while in aparasitaemic animals $27.71 \pm 3.78SD$ with a significant difference ($P < .001$). The PCV value in equine species ranges from 18 to 47% and the mean PCV value in parasitaemic animals was $23.75 \pm 4.66SD$ while in aparasitaemic animals $34.02 \pm 2.97SD$ with a significant difference ($P < .001$). When anaemic condition was measured by mean PCV of parasitaemic animals,

Table 2

The prevalence of bovine trypanosomosis with host related risk factors in selected districts of western Amhara region, Northwest Ethiopia during the study period.

Risk factor	Number examined	Number positive	Prevalence (%)	OR	95% CI		P-value
					Lower	Upper	
Districts							
Jabitehenan	184	11	5.98		3	3.3	
South Achefer	212	13	6.13	0.8	3	4	0.380
Dembecha	185	15	8.11	1.1	3.8	4.1	0.708
Jawi	222	21	9.46	1.6	3.8	4.7	0.185
Sex							
Female	376	25	6.6		2.4	2.6	
Male	427	35	8.2	1.7	2.5	2.7	0.069
Age							
Young	148	4	2.7		2.5	2.6	
Adult	655	56	8.5	4.2	2.1	8.6	0.008
^aBCS							
Good	194	5	2.6		0.2	7.7	
Medium	312	17	5.4	1.9	2.7	8.8	0.024
Poor	297	38	12.8	5.8	10	16.1	0.000
Color coat							
White	130	4	3.1		1.7	7.1	
Red	466	22	4.7	1.7	2.1	6.8	0.035
Black	207	34	16.4	6.2	12	19.1	0.000

^a BCS-Body condition score.**Table 3**

Prevalence of equine trypanosomosis with different risk factors in selected districts of western Amhara region, Northwest Ethiopia during the study period.

Risk factor	Number examined	Number positive	Prevalence (%)	OR	95% CI		P-value
					Lower	Upper	
Districts							
Jabitehenan	113	2	1.8		2.5	5.1	
Dembecha	112	3	2.7	0.3	1.6	6	0.142
South Achefer	113	6	5.3	0.4	1.1	8.7	0.271
Jawi	116	9	7.8	1.5	3.6	11.1	0.453
BCS							
Good	107	1	0.93		3.8	4.7	
Medium	173	3	1.73	4.7	1.0	7.1	0.041
Poor	174	16	9.19	8.0	3.8	10	0.001

Table 4

Comparison of mean PCV values in parasitaemic bovine between trypanosome species.

Parasite species	Number examined	Mean PCV \pm SD	t-value	(P-value)
<i>T. congolense</i>	48	20.23 \pm 2.354	-4.723	0.000
<i>T. vivax</i>	12	23.92 \pm 2.678		

both *T. congolense* and *T. vivax* infections reduced PCV, however, the PCV reduction in *T. congolense* infection was significantly higher ($P < .001$) compared to *T. vivax* infection (Table 4). The majority of trypanosome infection in equine was *T. congolense* and hence comparison on haematological effects with *T. vivax* was not done.

3.2. Entomological survey

A total of 187 flies were caught from deployed traps; out of these, 44.4% belonged to tsetse of the genus *Glossina*, and the remaining were biting flies shared by two genera namely *Tabanus* and *Stomoxys* which accounts 13% and 41.7%, respectively (Tables 5 and 6). Two species of tsetse were identified; *G. tachinoides* (62.65%) and *G. m. submorsitans* (37.35%). The tsetses caught were examined for sex. Accordingly 66.3% and 33.7% were females and males, respectively.

The highest mean apparent fly density catch for tsetse was found in Jawi (1.6), followed by South Achefer (1), Dembecha (0.8) and Jabitehenan (0.75) without a significant difference ($P = .262$). The highest mean apparent fly density for biting flies was found in Dembecha (1.95), followed by Jawi (1.3), South Achefer (1.05) and Jabitehenan (0.9) and the difference was significant ($P = .002$). The apparent fly density in different vegetation types (Fig. 3) showed significant difference both in tsetse and biting

Table 5

Apparent density (F/T/D) of flies in four districts of Western Amhara region, Northwest Ethiopia during the study period.

Districts	Number of traps	Fly species caught				
		<i>Glossina</i>	<i>Tabanus</i>	<i>Stomoxys</i>	Total	F/T/D*
Jawi	10	32	5	21	58	2.9
South Achefer	10	20	6	15	41	2.05
Jabitehenan	10	15	5	13	33	1.65
Dembecha	10	16	10	29	55	2.75
Total	40	83	26	78	187	2.34
F/T/D		1.04	0.32	0.97		2.34

F/T/D* - Fly/Trap/Day.

Table 6Mean catches of *Glossina* species based on sex in four districts of Western Amhara region, Northwest Ethiopia during the study period.

Districts	Number of traps	<i>G. m. submorsitans</i>		<i>Glossina tachinoides</i>		Total	F/T/D*
		Female	Male	Female	Male		
Jawi	10	–	–	20	12	32	1.6
South Achefer	10	–	–	13	7	20	1
Jabitehenan	10	11	4	–	–	15	0.75
Dembecha	10	11	5	–	–	16	0.8
Mean (F/T/D)		0.28	0.11	0.41	0.24		1.04

F/T/D* = Fly/Trap/Day.

flies ($P < .001$). Similarly altitude showed significant difference on the apparent densities in both tsetse and biting flies ($P < .001$) as shown in Fig. 4.

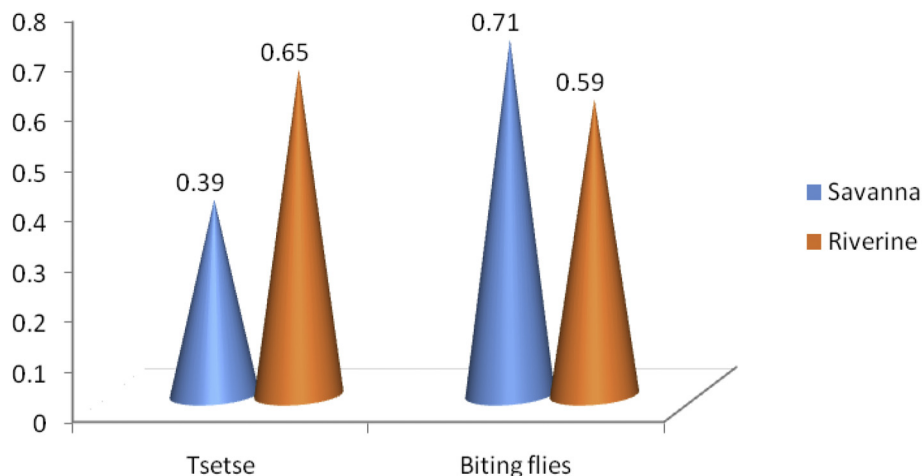
3.3. Questionnaire survey

3.3.1. Animal production constraints and status of trypanosomiasis

The majority of livestock reared in the study area were cattle followed by small ruminants and equine. The response of farmers on the constraints of livestock production were explained as diseases followed by lack of grazing land, watering points and scarcity of veterinary services. From livestock diseases the respondents indicated that trypanosomiasis was the first animal health problem in the study areas. The majority of farmers (59%) responded that trypanosomiasis was occurred from September–November followed by April–June (21%), July–August (12%) and October–May (8%).

3.3.2. Trypanosomiasis and tsetse control measures

The respondents of the questionnaire indicated that trypanosomiasis and tsetse control measures started before 5 years in South Achefer and Jawi districts while in Jabitehenan and Dembecha districts it started before 10 years but the control practice was not sustainable. The control measures were carried out by using trypanocidal drugs, and pour-on, traps and targets.

**Fig. 3.** Apparent densities of tsetse and other biting flies in different vegetation types.

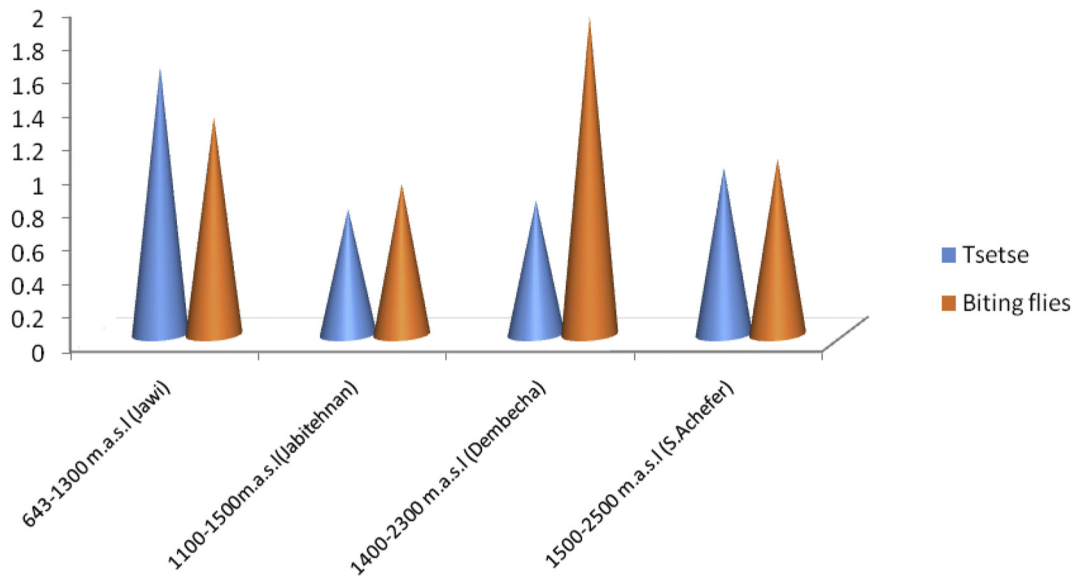


Fig. 4. Apparent densities of tsetse and other biting flies in different altitudes.

According to the respondents, trypanocidal drugs were mainly obtained from private drug shops followed by veterinary clinics and both. In South Achefer district about 75% and 25% of the treatment was delivered by farmers and veterinary personnel while in Jawi 46%, 13% and 41% by farmers, veterinary personnel and both, respectively. In Dembecha district about 30% and 70% of the treatments were given by farmers and both farmers and veterinary personnel, respectively while in Jabitehenan district 25%, 10% and 65% by farmers, veterinary personnel and both, respectively.

Similarly the respondents indicated that tsetse control was carried out by pour-on application, traps and targets two times per year i.e. before and after the long rainy season (in the months of May and October), respectively in Jawi and South Achefer district districts. However, in Dembecha and Jabitehenan districts tsetse control was interrupted before 8 years. All the interviewed farmers confirmed that the tsetse control program was essential and effective as it was reflected in the reduction of fly population and disease prevalence particularly in South Achefer and Jawi districts. The respondents also suggested as a witness, the targets that were deployed on the river side and in savanna grassland (Fig. 5) played a significant role in the reduction of fly population.

The respondents revealed that tsetse and trypanosomosis distribution were decreased after the implementation of control measures by 90% and 76% in South Achefer and Jawi, respectively. Furthermore, the farmers in South Achefer and Jawi districts were observed several changes including increased number of livestock, decreased mortality rate and treatment expenses, improvement in body condition and milk production, increased working efficiency and agricultural production. The livestock population number obtained from secondary data of district veterinary offices starting 2012–2016 was summarized in Table 7. Consequently the trend of livestock number showed increment mainly in South Achefer and Jawi districts.

The trend of costs incurred for trypanocidal drugs per year for 5 consecutive years (2012–2016) in the four districts of Western Amhara region is indicated in Fig. 6. As clearly shown on the figure in Jawi and South Achefer districts the cost incurred for treatment is minimal and showed reduction with time which might be associated with control practice while in Jabitehenan and Dembecha districts the drugs proportion in terms of costs is increasing with time.

4. Discussion

4.1. Parasitological findings

The current study indicated that trypanosomosis is a major constraint to cattle and equine production in the study areas. The parasitological examination revealed a prevalence of 7.47% for bovine trypanosomosis and 4.4% for equine trypanosomosis with *T. congolense* and *T. vivax* being the trypanosome species identified during the study period. The prevalence in equine was lower than that in bovine which might be associated with the fact that the preferred host for tsetse could be cattle and usually the latter graze over long distance (Radostits et al., 2007).

The prevalence of bovine trypanosomosis in the study districts was 9.46%, 6.13%, 8.11% and 5.98% for Jawi, South Achefer, Dembecha and Jabitehenan, respectively. Previous reports by Wolde-Mariam (1997) showed higher prevalence of 23.36% and 24.5% in Dembecha and Jabitehenan, respectively and Dagnachew et al. (2005, Dagnachew et al. (2011) with a total prevalence of 14.68% for Dembecha and Jabitehenan, and 11.3% in Jawi districts. On the other hand the current finding was in agreement with Kebede and Animut (2009) who reported 10.1% from Awi zone. The variation could be associated with the sampling season particularly shortly after rainy season the prevalence is higher as the density of vectors is expected to be high during this period.



Fig. 5. Target deployed for tsetse control in South Achefer district at Zehebest PA's.

Table 7

Livestock population in the study districts of Western Amhara region, Northwest Ethiopia from 2012 to 2016.

Year	Species	District			
		South Achefer	Jawi	Dembecha	Jabitehenan
2012	Bovine	164,844	91,359	129,686	128,923
	Equine	21,351	6351	13,547	10,304
2013	Bovine	186,540	97,449	133,027	143,489
	Equine	21,985	8246	15,847	11,326
2014	Bovine	191,791	128,233	135,296	163,238
	Equine	22,764	12,216	16,638	12,975
2015	Bovine	198,320	139,445	141,107	237,905
	Equine	24,550	24,845	16,769	15,628
2016	Bovine	206,524	213,544	147,798	242,726
	Equine	24,949	32,880	20,007	42,478

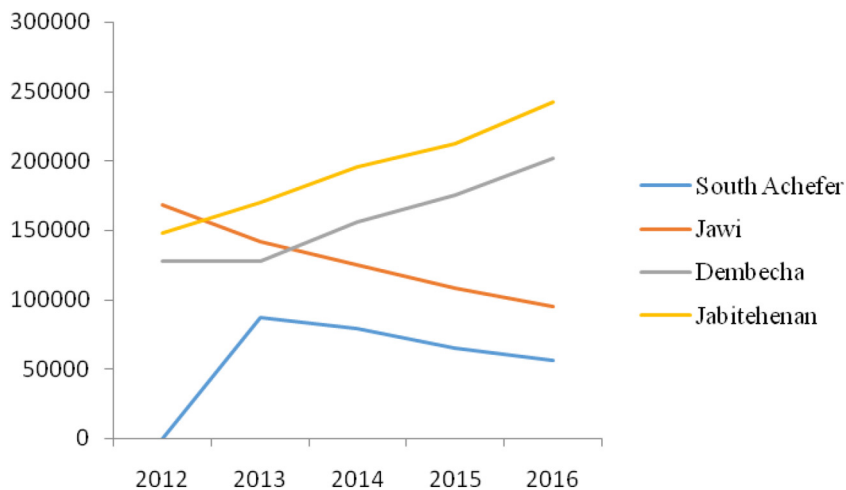


Fig. 6. The trend of costs in year incurred for trypanocidal drugs in the study areas.

Other possible explanation could be the treatment and control measures implemented in all districts, even though, the sustainability is questionable in Jabitehenan and Dembecha districts. The prevalence of equine trypanosomosis (4.4%) in the present study is lower than that of previous reports of 18.2%–28.5% in different district of Southern Ethiopia and 6.3% in Assosa and Homosha districts in Benishangul Gumuz, Northwest Ethiopia (Abebe and Wolde, 2010). The reduction in prevalence from previous reports might be attributed to season and control measure of tsetse and trypanosomosis.

The present study indicated that the prevalence of *T. congolense* was (80%) higher than the prevalence of *T. vivax* (20%) for bovine trypanosomosis. The high proportion of *T. congolense* detected in the study districts agreed with previous reports by Dagnachew et al. (2007) which was 58% due to *T. congolense*. That *T. congolense* was the dominant trypanosome species in equine was in agreement with the reports of Abebe and Wolde (2010) and Assefa and Abebe (2001). *T. congolense* in donkeys causes

chronic infection with longer persistence in the blood (Mattioli et al., 1994). The higher prevalence of *T. congolense* may also suggest that the major cyclical vectors or *Glossina* species (*G. m. submorsitans* and *G. tachinoides*) are more efficient transmitters of *T. congolense* than *T. vivax* in East Africa (Langridge, 1976).

All the mules examined in this study were found to be negative for trypanosome infection. Other than small sample size, this might be attributed to less contact of mules with the tsetse vectors as they are usually kept around villages unless needed for riding purposes. Unlike mules, donkeys are the major type of pack animals and often travel long distances across tsetse challenge areas during the day time when fly activity is high and might expose to tsetse fly bite.

Recently Leta et al. (2015) conducted a comprehensive meta-analysis of bovine trypanosomosis in Ethiopia and estimated it to be 8.12% which is in agreement with our finding. Previous and on-going tsetse control activities in the present study areas could be the reason for the observed reduction in the prevalence of trypanosomosis.

In the current study significant association ($P < .05$) was observed between age, body condition and hair color coat categories. Body condition is also an important indication for trypanosome infection both of the individual animal and of the herd level (Murray, 1979). Our finding is also agreed with the previous works by Solomon and Fitta (2010) in Awi and Metekel zones in Northwest Ethiopia. Similarly in equine body condition score was significantly associated with trypanosome infection i.e. poor BCS had higher prevalence than medium and good BCS. According to Seifert (1996), trypanosome infection causes a progressive loss of condition, weight loss and the animals become easily exhaustive. Since adult animals travel long distance for grazing and watering areas might contribute higher infection rates. Animals with black coat color were found to be highly infected than red and white coat color might be associated for *Glossina* species, the strongest landing responses were found to be on black surfaces (Leak, 1999).

One of the main symptoms of trypanosomosis is anemia (Murray, 1979), consequently, the present study also confirmed significant difference between mean PCV values of parasitaemic and aparasitaemic animals. Similar findings were reported by several researchers (Abebe and Wolde, 2010; Rowlands et al., 2001; Ali and Bitew, 2011; Bayisa et al., 2015; Mamoudou et al., 2015). Comparison of the mean PCV of infected animals between species of trypanosome indicated *T. congolense* infected animals had more reduced PCV than was the case with *T. vivax* infected animals. Mostly *T. vivax* invades other tissues in addition to blood such as lymph nodes, eyes and heart (Whitelaw et al., 1988) but *T. congolense* confinement in the blood might result in low PCV values.

4.2. Entomological survey

The entomological survey revealed that tsetse species in the study areas were *G. m. submorsitans* in Dembecha and Jabitehenan, and *G. tachinoides* in Jawi and South Achefer districts. This finding is in agreement with the report of Dagnachew et al. (2005) *G. m. submorsitans* the only species of tsetse in Dembecha and Jabitehenan. Similarly *G. tachinoides* and *G. m. submorsitans* were detected by Langridge (1976) and by (Tikubet and Gemechu (1984) in the Abbay, Beles and Didessa river valleys.

The overall mean catch of tsetse was 1.04 F/T/D during the study period. Our finding was not in agreement with the previous reports by Tilahun et al. (1997) who reported 16 F/T/D in Tana Beles valley and by Abebe and Regassa (2009) who reported 10.68F/T/D in upper Didessa valley. Such wide variations could have resulted from differences in season and density of vegetation cover and the control practices targeting the vectors in the current study areas. It may also be explained by the migration of reservoir game animals as a result of climate and habitat changes (Leak, 1999). Typical habitat pattern were found in the study area for the savannah species *G. m. submorsitans* which had preference for savanna grass land and *G. tachinoides* which prefer along the river side. Both of the identified tsetse species in the present study are among the five *Glossina* species recorded in Ethiopia (Keno, 2005). In the present study most of the tsetse were caught in the lowland area so that the apparent density decreases as altitude increases ($P < .05$). This finding supports earlier works by (35, 46, 40, 12] who indicated that climate, which is largely influenced by altitude has an impact on tsetse population. The presence of other biting flies such as *Stomoxys* and *Tabanus* in our study, which are potential vectors for the mechanically transmitted *T. vivax* in wider areas of the region where the tsetse are not found, has also been supported by previous researchers (Cherinet et al., 2006; Sinshaw et al., 2006).

4.3. Questionnaire survey

In the present study areas livestock diseases mainly trypanosomosis, lack of grazing land, watering points and scarcity of veterinary services were found to be the challenges for livestock production. This finding is supported by Dagnachew et al. (2005) who reported the same constraints in the Abbay basin areas of Northwest Ethiopia. Though, the level of precision depends on the experience of livestock keepers, most farmers could determine clinical signs suggestive of trypanosomosis that are commonly described for the disease (Holmes et al., 2004).

Farmers acknowledged that tsetse and trypanosomosis control program were present in their area. Consequently introduction of the intervention program reduced the infection and improved the productivity of animals. Similar observations in other areas indicated that tsetse control in Arbaminch Zuria district significantly reduced the prevalence of trypanosomosis and fly density (Seyoum et al., 2013). However, due to the long history of the disease in the study areas they accustomed the habit of frequent treatment of animals with diminazene aceturate and isometamidium chloride. Similar practices about the drugs used were reported by previous researches in many parts of the country (Dagnachew et al., 2017; Gechere et al., 2012). The amount of trypanocidal drugs utilized in 5 years record data indicated that there was reducing trend in Jawi and South Achefer districts

that could be associated with the active control measures implemented compared to Demebecha and Jabitehenan districts wherein only trypanocidal drug treatment was used while vector control program was not continued. This is partly substantiated with increased number of livestock observed from 2012 to 2016 which might be attributed to reduction in the prevalence trypanosomiasis in the former districts.

5. Conclusion

Trypanosomiasis is found to be the major livestock health constraint in the study areas, even though, different control measures has been implemented. The dominant species of trypanosomes identified in the study areas was *T. congolense*. Age, BCS and hair coat color in bovine while only BCS in equine were found to be significant risk factors in trypanosome infection rates. Similarly trypanosome infected animals had reduced mean PCV value as compared to non-infected animals. The species of tsetse fly caught in the study areas were *G. m. submorsitans* and *G. tachinoides*. Farmers in the study areas were familiar with trypanosomiasis and control methods. Consequently, reduction in prevalence and vector densities as well as farmers perception on the control measures of the disease is promising to improve the productivity of livestock in the study areas. However, sustainability of control measures should be given emphasis.

Declaration of Competing Interest

No conflict of interest among authors and any interested persons concerning to this manuscript.

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References

- Abebe, G., 2005. Review article: trypanosomiasis in Ethiopia. *Ethiop. J. Biol. Sci.* 4 (1), 75–121.
- Abebe, G., Jobre, Y., 1996. Trypanosomiasis: a threat to cattle production in Ethiopia. *Rev. Med. Vet.* 147, 897–902.
- Abebe, G., Regassa, F., 2009. Current epidemiological situation of bovine trypanosomiasis in limu shay tsetse control area of upper Didessa valley. *Ethiop. Vet. J.* 13, 20–33.
- Abebe, R., Wolde, A., 2010. Preliminary survey on equine trypanosomiasis and its vector in Assosa and Homasha districts of Benishangul Gumuz regional state, Northwest Ethiopia. *Livestock Res. Rurl. Devt.* 22 (1), 140–145.
- Ali, D., Bitew, M., 2011. Epidemiology of bovine trypanosomiasis in Mao-Komo special district, Benishangul Gumuz regional state, Western Ethiopia. *Glob. Veter.* 6, 402–408.
- Assefa, E., Abebe, G., 2001. Drug resistance of *T. congolense* in naturally infected donkeys in North Omo Zone, Southern Ethiopia. *Vet. Parasitol.* 99, 261–271.
- Bayisa, K., Getachew, D., Tadele, T., 2015. Bovine trypanosomiasis in Assosa district, Benishangul Gumuz regional state, Western Ethiopia: prevalence and associated risk factors. *Europ. J. Appl. Sci.* 7 (4), 171–175.
- Bedada, H., Dagnachew, S., 2012. Study on the prevalence of donkey trypanosomiasis in Awi zone Northwest Ethiopia. *Ethiop. Vet. J.* 16, 65–76.
- Brightwell, R., Dransfield, R.D., Korku, C.A., Golder, T.K., Tarimo, S.A., Mugnai, D., 1987. A new trap for *Glossina pallidipes*. *Trop. Pest Mngt.* 33, 151–159.
- Caren, M., 1997. *Medical Hand Book of Donkey for Professionals*. 3rded. Whittet Books Limited, 18Anley Road, London, pp. 19–36 W14 0BY.
- Cherenet, T., Sani, R.A., Speybroeck, N., Panandam, J.M., Nadzr, S., Van den Bossche, P., 2006. A comparative longitudinal study of bovine trypanosomiasis in tsetse-free and tsetse-infested zone of the Amhara region, Northwest Ethiopia. *Vet. Parasitol.* 140, 251–258.
- CSA, 2017. *Agricultural Sample Survey, Statistical Bulletin*. Addis Ababa, Ethiopia.
- Dagnachew, S., Sangwan, A.K., Getachew, A., 2005. The epidemiology of bovine trypanosomiasis in Abay (Blue Nile) basin of Northwest Ethiopia. *Revue Élev. Méd. vét. Pays trop.* 58 (3), 151–157.
- Dagnachew, S., Abebe, G., 2007. Studies on tsetse-transmitted trypanosomiasis in new settlement areas of Jawi and Quara districts of Amhara region northwest Ethiopia. In Proceedings of the 29th Meeting of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), Luanda, Angola, 1st–5th October.
- Dagnachew, S., Girma, H., Abebe, G., 2011. A cross-sectional study on bovine trypanosomiasis in Jawi district of Amhara region, Northwest Ethiopia. *Ethiop. Vet. J.* 15 (1), 69–78.
- Dagnachew, S., Tsegaye, B., Awukew, A., Tilahun, M., Ashenafi, H., Rowan, T., Abebe, G., Barry, D.J., Terefe, G., Goddeeris, B.M., 2017. Prevalence of bovine trypanosomiasis and assessment of trypanocidal drug resistance in tsetse infested and non-tsetse infested areas of Northwest Ethiopia. *Parasite Epid. Cont.* 2, 40–49.
- DeLahunta, A., Habel, R.E., 1986. Teeth. In: DeLahunta, A., Habel, R.E. (Eds.), *Applied Veterinary Anatomy*. W.B. Saunders Company, Philadelphia.
- FAO, 2009. Collection of Entomological Baseline Data for Tsetse Area-Wide Integrated Pest Management Programmes. Key for the Identification of Adults of the Species of *Glossina*. FAO (Food and Agricultural Organization of the United Nations), Rome.
- Gechere, G., Terefe, G., Belihu, K., 2012. Impact of tsetse and trypanosomiasis control on cattle herd composition and calf growth and mortality at Arbaminch district, Southern Rift Valley, Ethiopia. *Trop. Anim. Hlth. Prod.* 44, 1745–1750.
- Holmes, P., 2013. Tsetse-transmitted trypanosomes—their biology, disease impact and control. *J. Invertebr. Pathol.* 112 (Suppl.) S11–S14.
- Holmes, P., Maudlin, I., Miles, M., 2004. *The Trypanosomiasis*. CABI International Publishing, Wallingford, UK, pp. 1–634.
- Ilemobade, A.A., 2009. Tsetse and trypanosomiasis in Africa: the challenge and the opportunities. *Onderst. J. Vet. Res.* 76, 35–40.
- Kebede, N., Animut, A., 2009. Trypanosomiasis of cattle in selected districts of Awi Zone, Northwestern Ethiopia. *Trop. Anim. Hlth. Prod.* 41 (7), 1353–1356.
- Keno, M., 2005. The Current Situation of Tsetse and Trypanosomiasis in Ethiopia, Ministry of Agriculture and Rural Development, Veterinary Service Department: In Proceedings of the 28th Meeting of International Scientific Council for Trypanosomiasis Research and Control (ISCTRC). Addis Ababa, Ethiopia.
- Langridge, P.W., 1976. A Tsetse and Trypanosomiasis Survey of Ethiopia, Ministry of Overseas Development (Uk) and Ministry of Agriculture of the Ethiopia. pp. 1–40.
- Leak, S.G.A., 1999. *Tsetse Biology and Ecology: Their Role in the Epidemiology and Control of Trypanosomiasis*. CABI Publishing, Wallingford, Oxon, UK, pp. 152–210.
- Leak, S.G.A., Woume, K.A., Colardeue, C., Duffera, W., Feron, A., 1987. Determination of Tsetse Challenge and its Relationship with Trypanosomiasis Prevalence in Trypanotolerant Livestock at Sites of the African Trypanotolerant Livestock Network. The African Trypanotolerant Livestock Network, Nairobi, Kenya, pp. 43–52.
- Leta, S., Alemayehu, G., Seyoum, Z., Bezie, M., 2015. Prevalence of bovine trypanosomiasis in Ethiopia: a meta-analysis, parasite and vect. 9, 139.

- Mamoudou, A., Payne, V.K., Sevidzem, S.L., 2015. Haematocrit alterations and its effects in naturally infected indigenous cattle breeds due to trypanosoma spp. on the Adamawa Plateau - Cameroon. *Vet. World* 8 (6), 813–818.
- Martin, S.W., Meek, A.H., Wallenberg, P., 1987. *Veterinary Epidemiology. Principles and Methods*. Iowa State University Press, Ames.
- Mattioli, R.C., Zinsstag, J., Pfister, K., 1994. Frequency of trypanosomiasis and intestinal parasites in draught donkeys in the Gambia in relation to animal husbandry. *Trop. Anim. Hlth. Prod.* 26, 102–108.
- Molalegne, B., Yeshitla, A., Tilahun, Z., Hailu, D., 2010. Trypanosome infection rate in *Glossina pallidipes* and *Glossina fuscipes fuscipes* in Gojjeb valley, Southwest Ethiopia. *Glob. Veteri.* 6 (2), 131–135.
- Murray, M., 1979. Anaemia of bovine African trypanosomosis. In: Losos, G., Chouinard, A. (Eds.), *An Overview in Pathogenicity of Trypanosomes*. Ottawa, Canada, IDRC.
- Murray, M.P.K., McIntyre, W.I.M., 1977. An improved parasitological technique for the diagnosis of African trypanosomosis. *Trans. R. Soc. Trop. Med. Hyg.* 71, 325–326.
- Murray, M., Paris, J., McOimba, F., 1982. A comparative evaluation of the parasitological techniques currently available for the diagnosis of African animal trypanosomosis in cattle. *Acta Trop.* 39, 307–316.
- NEWC, National Equine Welfare Council, 2005. *Equine Industry Welfare Guidelines Compendium for Horse, Ponies and Donkey, Body Condition Scoring for Horse and Donkey*. 2nd ed. pp. 28–29.
- Nicholson, M.J., Butterworth, M.H., 1986. *A Guide to Condition Scoring of Zebu Cattle*. ILCA, Addis Ababa, Ethiopia.
- NTTICC, 2000. *Annual report, Ministry of Agriculture, National Tsetse and Trypanosomosis Investigation and Control Center (NTTICC)*. Bedelle Illubabor, Ethiopia, p. 29.
- OAU, 2001. *Trypanosomosis, Tsetse and Africa. The year book report*.
- Parryet, G.F., Mabey, R.D., Gill, F., 2004. *Principle of Medicine in Africa*. Cambridge University Press, London.
- Radostits, O.M., Gay, C., Blood, D.C., Hinchcliff, K.W., 2007. *Veterinary Medicine: A Text Book of the Diseases of Cattle, Sheep, Goats, Pigs and Horses*. 10thed. Harcourt Publishers' Ltd, London, pp. 1564–1569.
- Rowlands, G.J., Leak, S.G., Peregrine, A.S., Mulatu, W., 2001. The incidence of new and the prevalence and persistence of recurrent trypanosome infections in cattle in Southwest Ethiopia exposed to a high challenge with drug-resistant parasites. *Acta Trop.* 79, 149–163.
- Seifert, H., 1996. *Tropical Animal Health*. Kluwer Academic Publishers, Netherlands, p. 16.
- Seyoum, Z., Terefe, G., Ashenafi, H., 2013. 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.* 9, 214.
- Sinshaw, A., Abebe, G., Desquesnes, M., Yoni, W., 2006. Biting flies and *Trypanosoma vivax* infection in three highland districts bordering Lake Tana, Ethiopia. *Vet. Parasitol.* 141, 35–46.
- Solomon, M., Fitta, G., 2010. Survey on bovine trypanosomosis and its vector in Metekel and Awi zones of Northwest Ethiopia. *Acta Trop.* 117, 146–151.
- Thrusfield, M., 2005. *Veterinary Epidemiology*. 3rded. Black Well Science Ltd, pp. 233–250.
- Tikubet, G., Gemechu, T., 1984. Altitudinal distribution of tsetse flies in the Fincha valley (Western part of Ethiopia). *Insect Sci. Appl.* 5, 389–395.
- Tilahun, G., Balecha, F., Kassa, T., Hirre, B., Gemechu, T., 1997. Tsetse and Trypanosomosis Pilot Control Trial at Pawe Settlement Area Tana Beles Valley, Metekel Zone, Northwestern Ethiopia, Proceeding of 13th Conference of Ethiopian Veterinary Association. Addis Ababa, Ethiopia.
- Walle, R., Shearer, D., 1997. *Veterinary Entomology. Arthropod ectoparasites of veterinary importance*, London, UK, Champman and Hall, pp. 141–193.
- Whitelaw, D.D., Gardiner, P.R., Murray, M., 1988. Extravascular foci of *Trypanosoma vivax* in goats: the central nervous system and aqueous humor of the eye as potential sources of relapse infections after chemotherapy. *Parasitol.* 97, 51–61.
- Wolde-Mariam, S., 1997. Trypanosome survey in district of Abay valley in some Weredas of northwest Ethiopia, Amhara Region. *Bur. Agric.* 24.