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SEROPREVALENCE AND ASSOCIATED RISK FACTORS OF MAEDI-VISNA IN SHEEP POPULATION OF NORTH SHOA ZONE, ETHIOPIA

Enyiew Alemnew[1*], Tadiwos Asfaw[1], Chekol Demis[1], Fasil Aklilu[2], Yeshitla Wondifra[1], Mesfin Zewdu[3], Wondoson Kinfe[4]

[1]Debre-Birhan Agricultural Research Centre, Debre-Birhan Ethiopia
[2]National Animal Health Diagnostic and Investigation Centre, Sebeta, Ethiopia
[3]Debre-Birhan Sheep Breed Improvement and Multiplication Centre, Debre-Birhan Ethiopia
[4]Amed-Guya Sheep Breed Improvement and Multiplication Centre, Debre-Birhan Ethiopia

Abstract. Maedi-Visna causes a significant economical loss through morbidity, mortality and carcass weight loss in sheep worldwide. This cross-sectional study was conducted to determine the prevalence and associated potential risk factors of *Maedi-Visna virus* infection in the study areas. A total of 2009 serum samples were collected in the period from November, 2017 to October, 2019 and examined using indirect enzyme linked immunosorbant assays (I-ELISA) to screen antibodies against *Maedi-Visna virus*. The sensitivity and specificity of the test were 91.7% and 98.9%, respectively. The data were analyzed by using logistic regression. From a total samples tested 225(11.2%) were positive for the presence of antibodies against *Maedi-Visna virus*. There was statistical significance difference in seropositivity among sheep of different breeds, age group, production system and sexes ($P < 0.05$). This finding revealed that research centre and ranches were incriminated as a source for *Maedi Visna virus* infection and effective control measures have to be implemented through semi-annual testing and culling of all sero-reactor ewes and their progenies and regular screening test should be carried out during introduction of new flocks and before distribution of cross breed rams particularly from ranches and research centers to smallholder farmers. In addition; further epidemiological study should be done in future in sheep producing areas of the country to know the level of infection at regional and national level.

Keywords: *Antibody, Awassi, Dorper, Ranches, Serology.*

***Corresponding Author:** Enyiew Alemnew, Debre Birhan Agricultural Research Centre, Po. Box 112, Debre Birhan, Ethiopia, Phone: +251927681130, e-mail: alemnewenyiew@gmail.com*

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1. Introduction

Maedi-Visna is a chronic disease of adult sheep characterized by progressive interstitial pneumonia and other syndromes such as meningo encephalitis, indurative mastitis and arthritis. It is caused by a non-oncogenic which belongs to the subfamily *lentivirinae* (Radostitis *et al*., 2007). Transmission occurs more readily between dams and lambs *via* colostrum and milk, and among confined individuals probably *via* respiratory secretions (Preziuso *et al*., 2009).

Maedi-Visna is a slowly progressive disease of sheep and rarely goats which was first reported in the Iceland in 1939; and subsequently, has been reported in major sheep rearing countries throughout the world except Australia and New Zealand (Straub, 2004). In Ethiopia, Maedi-Visna is considered as an emerging disease; because it was introduced to the country together with imported sheep from abroad in the late1980's (Ayelet *et al*., 2001). An assessment made by Getnet *et a1.(* 2011) in and around the stocking and rearing centers of North Shewa showed that the disease became

one of the most economic important persistent diseases of respiratory system of sheep in the central Ethiopia; and antibody detection is a valuable tool for identifying virus carrier animals. As neither antiviral treatment nor vaccination is available, increasing the quality and efficiency of diagnostic tests is the possible methods to eradicate the disease (Shuaib *et al.*, 2010).

In Ethiopia, Ayelet *et al*. (2001) reported that a considerable number of sheep died with signs of respiratory embarrassment. Although, previous works of Tefera & Mulate (2016) showed the existence of Maedi-Visna in farms and breeding centers found in Eastern Amhara, Ethiopia very little attention has been given to the role of Maedi-Visna as the cause of production losses in sheep industries in Ethiopia. Therefore, taking into account the significance of the disease as one of the most important causes of economic losses in the study areas, the present study was designed to estimate the seroprevalence of Maedi-Visna in sheep and its associated risk factors in North Shewa Zone, Ethiopia.

2. Materials and methods

Description of the study areas

The study was conducted in selected areas (Debre-Birhan Agricultural Research Center on-station, Debre-Birhan Sheep Multiplication and Breed Improvement Center, Fadji and Amed-Guya Sheep Multiplication and Breed Improvement Center) of North Shoa zone Amhara Region, Ethiopia.

Debre-Birhan Agricultural Research Center (DBARC) on- station, Fadji, and Debre-Birhan Sheep Multiplication and Breed Improvement Center (DBSMBIC) are located around Debre-Birhan town at a distance of 110- 130 km North of Addis Ababa at a latitude between 9^0 3^0’ 26’’ to 9^0 64’92’’N and 9^0 3’ 26’’ to 39^0 27’ 37’’E longitude. These study areas are found in central highland of the country at an altitude of above 2770m. The annual rainfall of the study areas ranges from 950-1200mm and the mean annual minimum and maximum temperatures are 1.5 and 23.3^{0}C, respectively and the area experiences a bimodal rainfall patterns with a short rainy season which occurs from January to March and long rainy season which starts at the end of June and ends at early November (Tefera & Mulate, 2016).

Amed-Guya Sheep Multiplication and Breed Improvement Center (AGSMBIC), the other study area is situated around Mehal-Meda town of North Shoa zone of the Amhara Region. It has a geographical coordinate of 10^0 18’0” N, 39^0 40’ 0’’E with an altitude of 3132 above sea level which is located at a distance of 301km North East of Addis Ababa. The average temperature and the average annual rain fall of the area is 12.2^{0}C and 1149mm, respectively and the area experiences a bimodal rain fall patterns with a short rainy season which occurs from December to February and long rainy season which tarts in June and ends in Augest (Menz-Gera Livestock Offices, 2014, & www.ethiopiantreasures.co.uk/pages/climate.htm).

These study areas were selected purposively based on the history of Awassi cross bred sheep population and their distribution, proximity and accessibility to motor car road. Usually Awassi cross bred sheep were distributed around the highland areas of eastern Amhara which practiced the crop – livestock mixed production system.

Study animals and their management

The animals used for this study were short fat tailed indigenous breeds (Solomon *et al*., 2011), Awassi cross, Dorper cross and pure Awassi sheep and all were above six months of age. The age of each sheep was classified based on the dentations formula given by Geoff (2016) into young (< = 1year) and adult (> 1 years)). All sheep involved in this study were kept into extensive and semi-extensive management systems. In extensive management system, sheep were spent all the day on grazing pasture on fallow lands and crop residues usually with no extra-supplement and sheltered during the night. This management system was basically practiced in small holder sheep producers. Whereas, in semi-intensive production system, owners supplemented extra feed sources in addition to grazing. This production system was practiced by the research and sheep multiplication centers (Stephen, 2017).

Study design and sample size determination

Cross-sectional sero-epidemiological study was conducted on 2009 animals kept in different management systems of North Shoa zone from November, 2017 - October, 2019 to determine the prevalence of Maedi-Visna and its associated risk factors. A multistage stratified cluster sampling method was used in smallholder farmers, where as Census type sampling method was applied in DBARC, DBSMBIC and AGSMBIC (Martin *et al.*, 1988 & Thrusfield, 2007). The sample size for this study was determine based on the expected prevalence of 4% (Tefera & Mulate (2016)) and the 5% desired absolute procession and 95% confidence interval (CI)) according to Thrusfield (2005).

$$n = \frac{1.96^2 * P_{ex}(1 - p_{ex})}{d^2}$$

where *n* - required sample size, P_{ex} - expected prevalence (4%), d - desired absolute precision, and 1.96^2 - the value of z at 95% Confidence level.

Accordingly, the required sample size was59 sheep, but to increase the precision and accuracy, the sample size were maximized to 2009, about 34 folds.

Data collection and serological examination

Five ml of blood samples were collected directly from the jugular vein of each sheep using sterile vacutainer tubes and needles. The collected blood samples were leveled with specific animal codes and kept overnight at a room temperature to allow clotting. Then, the clotted blood samples in the tubes were centrifuged to obtain clear serum. Then the separated serums were carefully harvested in 1.8 ml cryo-vial and were preserved at -20ºC in deep refrigerator until they were processed. The test was carried out at Kombolcha Animal Health Diagnostic and Investigations laboratory, Amhara Region and at National Animal Health Diagnostic and Investigations Center, Sebeta, Ethiopia.

The serum samples were tested for the presence of antibody against *Maedi-visna virus* using I-ELISA, *Maedi-Visna Caprine Arthritis- Encephalitis virus* serum verification version *VISNAS ver 1217 EN* (IDvet, 310, Rue Louis Pasteur – Grabels – France). This kit allows a joint detection of the antibodies directed against both *Meadi-Visna virus* and *Caprine Arthritis- Encephalitis Virus* (Nowicka *et al*., 2014). At manufacturer cut-off of 50% sensitivity and specificity were 91.7% and 98.9% respectively (Nowicka *et al.,* 2014). The test was performed according to the manufacturer`s instruction manual (OIE 2008).

Data management and statistical analysis

All data collected for this study were entered in Ms-Excel spread sheet, arranged and analyzed using SPSS version 20.0 software. Descriptive statistics were used to estimate the sero-prevalence of *Maedi-Visna virus* antibodies in the study areas. Univariable logistic regression was used to identify significantly important risk factors such as breed, age, and sex and production system for the occurrences of *Maedi-Visna virus antibodies*. A test value at $p < 0.05$ was considered as statistically significant

3. Result

In this study a total of 2009 sheep serum samples were collected to identify antibodies for *Maedi-Visna virus* using I-ELISA serological test. Of total samples tested, 225(11.2%) were positive for the presence of antibodies against MVV in the study areas. The highest and the lowest seroprevalence were in DBARC (63.5%) and Fadji (0.8%) as shown in Table 1.

Table 1. Seroposetivity to *Maedi-Visna virus* antibodies in sheep detected by I-ELISA from study areas

Study areas	No. of sampled	No. of positives	Prevalence (%)
AGSMBIC	501	90	18.0
DBARC on station	52	33	63.5
DBSMBIC	1331	101	7.6
Fadji	125	1	0.8
Total	2009	225	11.2

The univariable logistic regression odd ratio model analysis of attribute risk factors indicated that a statistical significance difference in seropositivity between young (2.5%) and adult (12.5 %) sheeps ($p = 0.000$, OR = 5), and production systems ($p = 0.004$, OR = 18.6) the prevalence of positive case was higher in semi intensive (11.9%) than in extensive smallholder farmers (0.8%). Similarly, there were significant differences in sero-prevalence among different breeds and between sexes ($p < 0.05$) (Table 2).

Table 2. Univariable logistic regression analyses (LR) of risk factors with Maedi-Visna sero-positivity in sheep in North Shoa zone Amhara Region

Risk factors		No. sampled	No. positive	Prevalen-ce (%)	P - value	OR	CI (95%)
Breed	Pure Awassi*	93	5	5.4	-	-	-
	Dorper Cross	132	8	6.1	0.279	1.917	0.590 – 6.228
	Awassi Cross	1651	191	11.6	0.015	3.277	1.259 – 8.530
	Local	133	21	15.8	0.009	4.116	1.421 – 11.925
Sex	Female*	1905	203	10.7	-	-	-
	Male	104	22	21.2	0.000	3.341	1.938 – 5.760
Age	Young*	285	7	2.5	-	-	-
	Adult	1724	218	12.6	0.000	5.085	2.336 – 11.067
Production system	Extensive *	125	1	0.8	-	-	-
	Semi-Intensive	1884	224	11.9	0.004	18.572	2.515 133.940
Total		2009	225	11.2			

4. Discussion

Maedi-Visna causes a significant economical loss through morbidity, mortality and carcass weight loss in sheep worldwide. A sero- epidemiological study on Maedi-Visna has been conducted at different times in various countries including Ethiopia. The result of the present study conducted from purposively selected areas of North Shoa zone, Amhara Region, Ethiopia showed an overall seroprevalence of 11.2% Maedi-Visna infection in sheep.

The 11.2% prevalence of Maedi-Visna in this study is comparable with the reports of Tsegaw & Ademe (2012) 15.6% in eastern Amhara Region, Ethiopia, Preziuso *et al.* (2010) 15.3% in Turkish sheep, and Fournier *et al. (*2006), 15.6% in culled ewes in Alberta, Canada. However, the sero-prevalence result of the present study is much higher than the previous reports of Tefera & Mulate (2016) 4% in four districts of eastern Amhara Region, Ethiopia, Shuaib *et al.* (2010) 2.41% in Manitoba and much lower than many of the previous reports in Ethiopia, viz. 70.4% in Sheno Agricultural Research Center (Seyoum *et al.,* 2011), 62.5% in central cool highland (Garedew *et al.,* 2010), 20% in Arsi, Ethiopia (Getnet *et al.,* 2010), 88% in Debre-Birhan sheep breeding center (Getnet *et al.,* 2010), and 74% in central Ethiopia (Woldemeskel *et al*., 2002).

The finding in this study is also much lower than the reports from other countries of the world. For instance, 19% in Canada (Simard & Morley, 1991), Hüttner *et al.* (2010), 28.8% in Germany, Azkur *et al.* (2011) 19.4% in Kirikkale district, Turkey, Gerstner *et al.* (2015) 18% in Wyoning sheep, USA, and Norouzi *et al.* (2015), 29.6% in Khorasan-e- Razawi province, Iran. Such inconsistency in the prevalence rates of Maedi-Visna may be due to the variation in the diagnostic tests, sampling method used, the prevalence variability within the population studied, the characteristics of the animals forming the population, susceptibility of different breeds to the disease, management practices and measures taken to control the disease.

This survey showed a variation in sero-prevalence of Maedi-Visna between different study districts (0.8% to 63.5%). Similar results were obtained in different parts of Ethiopia (0.6% to 88%) (Getnet *et al*., 2010), in Quebec (14.5% to 69 %) (Shuaib *et al.,* 2010), and in Iran (6.7% to 72. 2%) (Norouzi *et al.,* 2015). This geographic difference in distribution of positive cases could be explained by the introduction of carrier animals from an infected area to disease free zones, the management practices and the bio-security followed by farm owners. The seroprevalence finding in Fadji was quite amazing, because this study area is geographically located far from severely affected research center, sheep multiplication and breed improvement ranches, and one can suggested that the disease might have been spread along with cross breed rams which were distributed for breeding purpose in the area. This hypothesis is supported by the reports of Garedew *et al. (*2010) & Seyoum *et al.* (2011) who investigated seroreactor rams in the villages obtained from sheep ranches a year ago.

The age related seroprevalence of *Maedi-Visna virus* infection in present study showed statistical significant difference ($p < 0.001$) between age groups, which disclosed that adult sheep were about five times more likely to be infected as compared to younger sheep. In this regard, the finding of this study is consistent with the results reported elsewhere. viz, in Ethiopia (Ayelet *et al.,* 2001; Tefera & Mulate, 2016), in Turkey (Preziuso *et al.,* 2010) & in Iran (Norouzi *et al.,* 2015). This age sero-prevalence discrepancy can probably be explained by the longer exposure to horizontal transmission and development of detectable levels of MV antibodies can vary from

months to years (Radostits *et al.,* 2000). Thus, the older the animals, the greater the potential for a greater proportion of sheep to be become infected with MVV.

There was significant difference in seroprevalence of Maedi-Visna among different breeds ($p < 0.05$); Dorper cross, Awassi cross and local were two, three and four times more likely to be infected as compared to pure Awassi sheep breed, respectively. This result is in line with the results reported by Seyoum *et al.* (2011), Tsegaw & Ademe (2012). This breed susceptibility difference could be related to the influence of traits of particular family lines, the strain of the virus and the result of one or more recessive genes (Simard & Morley, 1991). In this regard, the finding of this study was in contrast with the results reported by Tefera & Mulate (2016).

There was significant variation ($p < 0.01$) between the prevalence of Maedi-Visna in sheep kept under different production systems. Sheep kept under semi-intensive management system were about 18.6 times more likely to be infected than animals kept under extensive management system. The present result is in agreement with previous finding of Ayelet *et al*. (2001) who reported lower prevalence (3.7%) of Maedi-Visna in village flocks and relatively higher (7%) in on-station. Woldemeskel *et al.* (2002) and Tsegaw & Ademe (2012) also reported higher seroprevalence 74% and 30% of Maedi-Visna in clinically moribund sheep at ranches than in smallholder farmer, respectively. This seroprevalence difference between the two management systems might be associated with the flock size of the farms, the housing of the animals for longer hours during cold seasons, mixing different breeds and age groups and keeping high proportion of older animals in ranches. Baumgartner *et al.* (1990) have reported that unfavorable housing conditions such as insufficient room, bad climatic conditions and crowding behavior in sheep promote a high incidence of the disease.

There was significant variation ($p < 0.001$) between males and females sheep. In this regard, males were three times more likely to be infected than females' sheep. This finding is in agreement with findings of Tsegaw & Ademe (2012) and Simard & Morley (1991) who reported a higher seroprevalence in male than in female sheep. This difference could probably be rams were longer and repeat exposure to different female flocks during mating, thereby favoring horizontal transmission of the infection easily between animals. In contrast to our finding, Woldemeskel *et al*. (2002), Seyoum *et al.* (2011) & Tefera & Mulate (2016) reported that both sexes have equal chance to have the infection.

5. Conclusion and Recommendations

Even though, the sero prevalence of Maedi-Visna in the present study seems like lower in North Shoa Zone. However, the economic losses from Maedi-Visna disease could be huge due to impairing production and productivity of infected sheep. The finding of positive serological reactors does not only suggest the occurrence of the disease in sheep population of the study areas, but also indicates the presence of foci of infection that could serve as source of infection for the spread of the disease into unaffected animals around the study areas and to other sheep producing areas which receive cross breed sheep for upgrading of local sheep and also through marketing. Research center and sheep breeding and multiplication ranches are considered as sources of *Maedi-Visna virus* infection. Therefore, effective control measures should be implemented, through screening test during introduction of new flocks to multiplication centers and raches and before distribution of Awassi and Dorper cross breed rams from

different ranches and research centers to smallholder farms and also annual testing and culling of all sero-reactor ewes and their progenies. In addition; further epidemiological study using more sensitive test should be done in sheep producing areas of the country to know the level of the disease at regional and national level.

Conflict of interest

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript.

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References

Ayelet, G., Roger, F., Tibbo, M., Tembely, S. (2001). Survey of Maedi-Visna (MV) in Ethiopia highland sheep. *Vet. J.*, 161, 208-210.

Azkur, A., Gazyagci, S., Aslan, E. (2011). Serological and Epidemiological Investigation of *Bluetongue, Maedi-Visna* and *Caprine Arthritis-Encephalitis Viruses* in Small Ruminant in Kirikkale District in Turkey. *Kafkas Universitesi Veteriner Fakultesi. Derg*., *17*(5), 803-808.

Baumgartner, W., Reckinger, M., Pernthaner, A., Leitold, B. (1990). The occurrence and distribution of *Maedi-Visna virus* infection in lower Australian sheep breeding establishments. *Dtsch. Tierar. Wochen*., 97, 465-469.

Ethiopian Treasures 2002 Retrieved September 16, 2015, from: www.ethiopiantreasures.co.uk/pages/climate.htm

Fournier, D., Cambell, J., Middleton, D. (2006). Prevalence of Maedi-Visna infection in culled ewes in Alberta. *Can. Vet. J.*, 47, 460-466.

Garedew, G., Ayelet, G., Yilma, R., Zeleke, A., Gelaye, E. (2010). Isolation of diverse bacterial species associated with Maedi-Visna infection of sheep in Ethiopia. *Afr. J. Microbiol. R. 14*(1), 14-21.

Geoff, 2016. How to tell the age of sheep. Primefact 1481, 2nd ed. NSW Department of prim. Indu., July 2016. ISSN 1832-6668.

Gerstner, S., Adamovicz, J., Duncan, J., Laegreid, W., Marshall, L., Logan, J., Schumaker, B. (2015). Prevalence of and risk factors associated with *ovine progressive pneumonia* in Wyoming sheep flocks. *J. Amer. V. Med. Assoc*., *247*(8), 932-937.

Getnet, A., Asegedech, S., Hassen, C. (2010). Seroepidemiological study on Maedi-Visna in selected areas of Ethiopia. *Ethio.Vet. J., 14*(1), 101-111.

Hüttner, K., Seelmann, M., Feldhusen, F. (2010). Prevalence and risk factors for Maedi-Visna in sheep farms in Mecklenburg-Western-Pomerania. *Berl. Münch*., 123, 10–14.

Martin, S.W., Meek, A.H., Welleberg, P. (1988). Veterinary epidemiology/ principles and Methods, Chapter 2, 30-31.

Menz Gera Livestock Office (2014). Agro-ecological information for Menz Gera Mider District, Mehal Meda, Ethiopia.

Morris, S.T. (2017). Overview of sheep production systems. In *Advances in sheep welfare* (pp. 19-35). Woodhead Publishing.

Norouzi, B., Razavizade, A., Azizzadeh, M., Mayameei, A. Mashhadiv, S. (2015). Serological study of small ruminant *lentiviruses* in sheep population of Khorasan-e-Razawi province in Iran. *Vet. R.*, *6*(3), 245-249.

Nowicka, D., Czopowicz, M., Mickiewicz, M., Szalus-Jordanow, O., Witkowski L., Bagnicka, E., Kaba, J. (2014). Diagnostic performance of ID screen *MVV-CAEV* Indirect screening ELISA in identifying small ruminant *lintivirus* infected goats. Polish. *J. Vet. Sci., 17*(3), 501-506.

OIE (Office International des Epizooties), 2008. Caprine Arthritis- Encephalitis and Maedi-Visna. Manual of Diagnostic Tests and Vaccines for Terresterial Animals. Office International des Epizooties (OIE), http://www.oie.int/eng/normes/mmanual/a_summry.htm

Preziuso, S., Erman, O., Gimmarioli, M., Kyar, A., Feliziani, F., Gonul, R., Farneti, S., Yaramis, C., Valente, C., Cuteri, V. (2010). *Maedi-Visna virus* in Turkish sheep: a preliminary serological survey using ELISA test. *Turk. J. Vet. Anim. Sci. 34*(3), 289-293.

Preziuso, S., Sanna, E., Sanna, M., Loddo, C., Cerri, D., Taccini, E., Mariotti, F., Braca, G., Rossi, G. (2009). Association of *Maedi Visna virus* with *Brucella ovis* infection in rams. Europ. *J. Histochem*., *47*(2), 151-158. https://doi.org/10.4081/821.

Radostitis, O.M., Blood, D.C., and Gay, C.C. (2007). *Ovine progressive pneumonia* (Maedi-Visna).In: Veterinary Medicine. A Textbook of Cattle, Sheep, Goats, Pigs and Horses, 9th ed. London, Baillieretn, Tindall, 1071-1075.

Radostits, O.M., Gay, C.C., Hinchcliff, K.W., Constable, P.D., Jacobs, D.E., Ikede, B.O., ... & Bildfell, R.J. (2007). *Veterinary medicine: a textbook of the diseases of cattle, sheep, pigs, goats and horses*. 9th ed., Harcourt publishers limited, London Philadelphia, 701-967.

Seyoum, Z., Molalegne, B., Mekonen, T., Esayas, G. (2011). Evaluation of control program of Maedi-Visna by foster feeding with cow colostrums and other measures. *Glob. Vet.*, *6*(1), 96-96.

Shuaib, M., Green, C., Rashid, M., Duizer, G., Whiting, T. (2010). Herd risk factors associated with seroprevalence of Maedi-Visna in the Manitoba sheep population. *Can. Vet. J.*, 51, 385-390.

Simard C., Morley, R. (1991). Seroprevalence of Maedi-Visna in Canadian Sheep. *Can. J. Vet. R.*, 55, 269-273.

Solomon, G., Komen, H., Hanote, O., van Arendonk, J.A.M., Kemp, S., Aynalem, H., Mwai, O., Tadelle, D. (2011). Characterization and conservation of indigenous sheep genetic resources: A practical framework for developing countries. ILRI Research Report No. 27. Nairobi, Kenya, ILRI.

Straub, O.C. (2004). *Maedi-Visna virus* infection in sheep. History and present knowledge. *Comp. Immunol. Microbiol. Infect. Dis*., *27*(1), 1-5.

Tefera, N., & Mulate, B. (2016). Seroprevalence of Maedi-Visna in sheep in selected districts of Amhara region, Ethiopia. *Bulletin of Animal Health and Production in Africa*, *64*(4), 423-430.

Thrusfield, M. (2005). *Sampling In: Veterinary Epidemiology*, 3rd ed London: Black Well Science Ltd, 179-284.

Thrusfield, M. (2007). *Sampling In: Veterinary Epidemiology*, 3rd ed London: Black Well Science Ltd, 179-284.

Tsegaw, F., Ademe, Z. (2012). Serological survey of *Maedi-visna virus* infection in highland sheep at ranches and smallholder farms in eastern Amhara Region, *Bulletin of Animal Health and Production in Africa*, *60*(3), 287-295.

Woldemeskel, M., Tibbo, M., Potgieter, L. (2002). *Ovine progressive pneumonia* (Maedi-Visna): An emerging respiratory disease of sheep in Ethiopia. *Dtsch. Tierar. Wochen*., 109, 486-488.