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Beekeeping diseases and pests in east and west Gojjam zones of Amhara region, Ethiopia

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Abstract

The study was conducted in West and East Gojjam Zones of Amhara Region to determine the occurrence of honeybee diseases, pests and predators. Questionnaire survey and laboratory diagnostic methods were used for the study. In the questionnaire survey, 384 respondent beekeepers were interviewed. Similarly, for laboratory work 194 honeybee colonies sampled in apiary sites and backyard beekeeping management system were examined for the presence of honeybee pests, external parasites and disease pathogens. Descriptive, frequency and chi-square (x^2) test with SPSS version 20 were used. Affecting honeybee colonies were ants (17.4%), wax moth (16.7%), birds (16%), praying mantis (12%) honey badger (12%), bee lice (10.9%), small hive beetle (10.6%), wasp (4.8%), snake (2%) and lizards (1%). The major beekeeping constraints were absconding (22.8%), scarcity of bee forage (11.9%), agro-chemical application (11.8%), drought (11.2%), lack of technical skill (poor honeybee colony management) (10.6%), honeybee diseases (10.2%), scarcity of water (9.7%) and lack of credit (8.1%) and high costs of improved inputs for beekeeping (3.4%). During internal and external hive inspection pests and predators were observed. In the laboratory diagnosis results, colony level prevalence of Varroa mite, bee lice, Nosema apis and amoeba was 78.35%, 11.34%, 51.03% and 98.72%, respectively with different risk factors at chi-square test. Their statistical significance was tested at $P<0.05$ variation in overall prevalence which is varroa mite statistically significant at $P<0.05$ in colony management type and location. Hive type, study location and Amoeba was statistically significant at $P<0.05$ in study location.

Keywords: Gojjam, honeybee, honeybee disease, pests and predators

Introduction

Ethiopia is one of the countries in the continent, with huge honey production potential owing to its varied ecological and climatic conditions. Ethiopia is home to some of the most diverse flora and fauna in Africa (Nuru Adgaba, 2002) [34]. Its forests and woodlands contain diverse plant species that provide surplus nectar and pollen to foraging bees. The ideal climatic conditions and diversity of floral resources allow the country to sustain around 10 million honeybee colonies, of which 7 million are kept in local beehives by farmers and the remaining, exist in the forests as wild colonies making the country to have the highest bee density in Africa (Nuru Adgaba, 2002) [34]. Ethiopia, having the highest number of bee colonies and surplus honey sources of flora, is the leading producer of honey and beeswax in Africa.

Beekeeping is economically important activity that generates income for millions of people in Ethiopia and the world at large. Bee keepers earn income from direct sale of hive products such as bee colony, honey, beeswax, propolis, royal jelly and from products made up of honey and beeswax like honey beer, candle waxes, polish and cakes (Arse Gebeyehu *et al.*, 2010) [4]. In developed countries, beekeepers also earn considerable income from the pollination service that honeybees provide (Arse Gebeyehu *et al.*, 2010) [4]. Beekeeping remains to be one of the most profitable areas in the agricultural sector which has not been exploited yet to its full potential (Arse Gebeyehu *et al.*, 2010) [4].

It is estimated that the country has the potential to produce 500,000 tons of honey per annum. The recent production, however, is 53,675 tons of honey (CSA, 2016) [11]. In Amhara Region, beekeeping is a deep-rooted household activity and an integral part of the life style of the farming communities documented to own more than 1,328,235 honeybee colonies (CSA, 2016) [11]. During the production season the Amhara Region has produced about 9,925 tone of honey (CSA, 2016) [11]. The above figure shows that the country is producing less than 10% of its potential.

Rachna and Kaushik (2004) [35] reported that wax moths and wasps cause heavy losses to beekeepers throughout the world. In addition to these pests, bee lice, hive beetles, mites, ants, birds, rodents and mammals occasionally attain the status of serious pests in a particular situation. Virtually, honey bee *(Apis mellifera* L.) is susceptible to infection with viral, fungal, bacterial and protozoan pathogenic organisms (Hailegebriel Tesfay, 2014) [27].

Pests and predators cause a serious devastating damage on honeybee colonies within a short period of time. The major bee pests and predators detected in beekeeping practice in Ethiopia are mites, spider, bee-eater birds, and lizards are the most serious problems to beekeeping development in the country (Sisay Fikadu *et al.*, 2015) [37]. According to Kerealem Ejigu *et al*. (2009) [29] the main constraints of apiculture sub sector in Amhara Region are pesticides poisoning, honeybee pests and diseases. Adeday Gidey *et al*. (2012) [1], Dabessa Jatema and Belay Abebe (2015) [12] reported that the existence of pests and predators were a major challenge to the honeybees and beekeepers in Tigray and Oromiya Regions respectively. The major pests and predators are ants, wax moth (*Galleria mellonella*), bee lice (*Braula coecal*), beetles (*Aethina tumida*), spiders, wasps, praying mantids, lizards, snakes, birds and honey badger (*Mellivora capensis*).

Hailegebriel Tesfay (2014) [27] also reported Chalkbrood diseases caused by pathogenic fungi, *Ascosphaera aphis*, Nosematosis caused by *Nosema apis* and amoeba caused by a single protozoa *Malpighamoeba mellificae* and a number of invertebrate pests belonging to Arthropods such as ants, beetle, moths, lice, termites, mites, and large vertebrate animals such as amphibians, reptile, lizards, birds, mammals like honey badgers and mice as a major honey bee enemies in Ethiopia.

Ethiopian environment is not only favorable to bees, but also for different kinds of honeybee pests and predators that are interacting with the life of honeybees.

Diseases and the recent honeybee pests phenomenon in Ethiopia, like: Chalk brood, small hive beetle, and *Varroa* mite have strongly pronounced the importance of assessing the honeybee health and health risks (Desalegn Begna, 2000 and 2006) [15, 16] in the country.

Apparently, identification, distributions and infestation levels of economically important honeybee diseases, pests and predators have not been well documented in the study area. Some research information is available on pesticide effects on honey bees and constraints of the sub-sector.

To maximize the production and productivity of apiculture and to fully exploit the opportunities well planned intervention strategies are needed to address the constraints and detecting the occurrence and mapping out the distributions of honeybee health problems is key step to start with. Some research findings support this research idea of which Desalegn Begna (2015) [17], reported that immediate research should be launched to determine disease free and infested areas for instance for varroamites and other honeybee pathogens.

The identification and severity of each economically important honeybee pests, disease and external parasite effects on honeybee have not been well documented in the study area; hence there is little information available about them. To fully exploit the opportunities in beekeeping sector, addressing the constraints and detecting the occurrence and distributions of honeybee's health problems and beekeepers cultural control mechanisms are key steps to prevent their harmful effects.

Therefore, the study was carried out aiming to assess honeybee diseases, pests and predators in the study areas: with the specific objectives:

- Identify types and distribution of honeybee pests and predators
- Identify types and distribution of honeybee diseases

Materials and Methods

The study was conducted in West and East Gojjam Zones of the Amhara National Regional State of Ethiopia in (Bure Zuria, and Awabel).

Burie zuria "Woreda"

Burie Zuria "Woreda" is located in West Gojjam Zone of the Amhara National Regional State in North-Western Ethiopia. The "Woreda" is approximately located between 10º17'-10º 45'N latitude and 37º00'-37º10'E longitude. Burie town, its capital, is located North-West of Addis Ababa at a distance of 410 km on the main highway through Debre Markos to Bahir Dar. It is bordered on the south by Blue Nile (Abay) River which separates it from Oromiya Region; on the west by Wemberma Woreda, on the northwest by the Agew-Awi Zone, on the north by Sekela Woreda, on the east by Jabi-Tehnan Woreda, and on the southeast by Dembecha and Misraq Gojjam Zone. The altitude of the Woreda varies from 1,500 - 2,400 masl. Before the establishment of the current Burie town administration, Burie "Woreda" had 18 rural, 4 semi-urban and 5 urban Kebeles with a total area of 838.9km^2 land, inhabited by overall human population of about 175 thousand; its livestock population consists of 90,475 cattle, 52,304 sheep, 13,523 goats, 6,716 donkeys, 620 horses, 228 mules and 10,499 honeybee colonies.

Topography of the Woreda is estimated to be 76% plain, 10% mountainous, 7% undulating, and the rest 7% valley (BDAOR, 2015) [8]. The three traditional agro-ecological zones found in Burie "Woreda" are mid-land (77.2%), semi-lowland (21.8%) and highland (1%). The mean daily temperature ranges from 17 to 25º C; and elevation ranges from 700 masl in the Abay gorge to 2350 masl at Jib-Gedel Kebele in the highlands. The annual rainfall pattern was mono-modal starting from June to September which receives annual rain fall of 1,000 to 1,500 mm.

The plain topography combined with the availability of optimum climatic and fertile soil condition makes the "Woreda" suitable for mixed crop-livestock production. Cultivated land, shrub land, and grazing land account for about 36.3%, 27.6%, and 17.1%, respectively, of the total area of the district (BoFEDANRS, 2005) [10]. The farming system of the "Woreda" was categorized to the mixed crop-livestock production system; the farmers used their land mainly for cropping purpose. Annual crops maize, wheat, hot pepper and millet, were the top four major crop types widely produced in the "Woreda", and more specifically the majority of maize and wheat production is comes from sub-lowland agro-ecology (BDAOR, 2015) [8].

Description of Awabel "Woreda"

Awabel "Woreda" is located in East Gojjam Zone. Its approximate coordinates are 10º15' N latitude and 37º56' E longitude. Lumamie, the "Woreda" capital, is located north west of Addis Ababa at a distance of 257 km on the main highway through Dejen leading to Bahir Dar. It is bordered on the south by the Abay River which separates it from the Oromia Region, on the west by Aneded Woreda, on the northwest by Sinan Woreda, on the northeast by Debay Telatgen Woreda, and on the east by Dejen. The "Woreda" has 28 rural and 3 urban Kebeles with a total area of 742.9 km^2 inhabited by an overall human population of about 176 thousand. Its livestock population includes 219,459 cattle, shoats 98,478, equine 38,786, chicken 42,957 and 8,356 honeybee colonies. The three traditional agro-ecological zones found in Awabel "Woreda" are mid-land (60%), semi-low land (25%) and highland (15%) with average altitude of 2,290 masl. The annual rainfall pattern is mono-modal extending from June to September ranges from 1,100 to 1,400 mm with average 1,250 mm and annual average temperature of 22.5 °C which ranges from 19 °C to 26 °C.

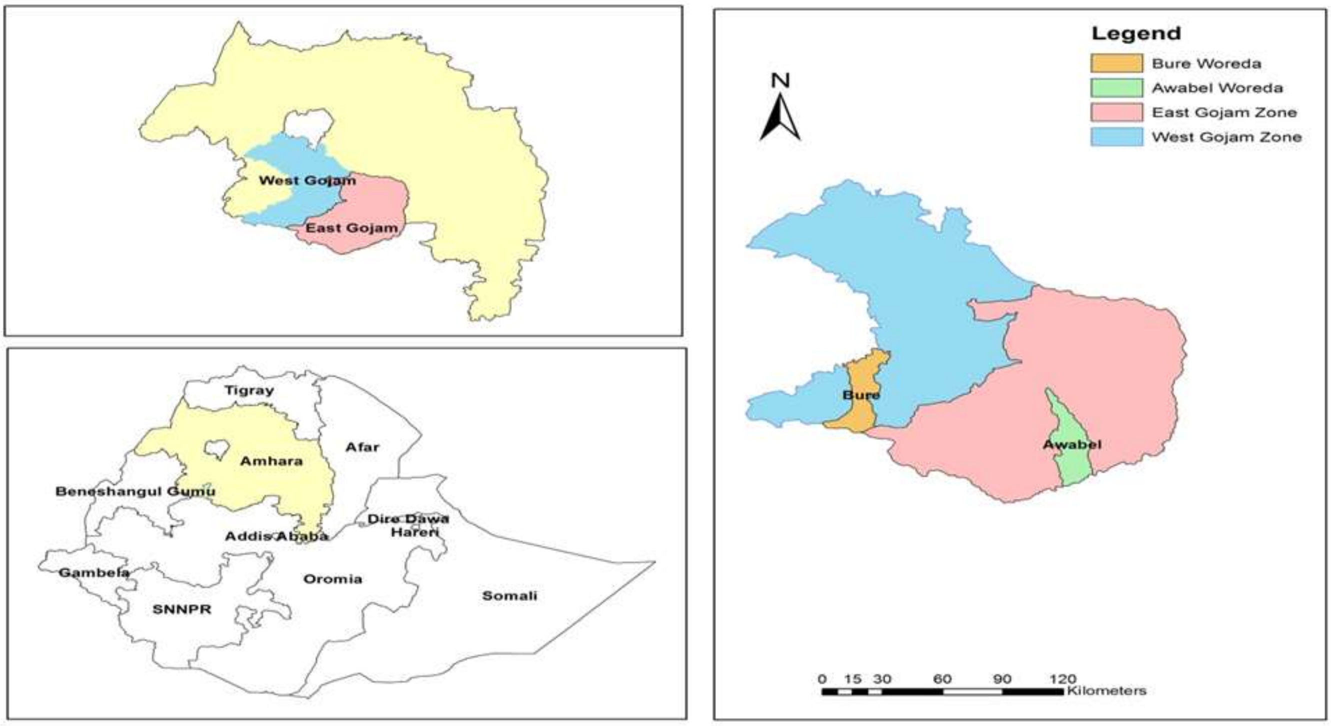

Fig 1: Map of study area

Regional distribution of honeybee colony in Ethiopia is higher in Oromiya Region (55%) followed by Amhara Region (19.35%) from the total honeybee colonies found in Ethiopia, which is distributed in each Zone of Amhara Region (Table 1).

Table 1: Amhara region honeybee colony zonal distribution and regional share of each zone

Zone	Area coverage		Honeybee resource		Honeybee colony per km^2
	Km^2	Regional share	Honeybee colony	Regional share	
North Gonder	45,561	28.26	273,700	22.02	6.01
South Gonder	20,061	12.44	191,344	14.88	9.54
North Wolo	10,177	6.31	44,404	5.65	4.36
South Wolo	17,462	10.83	186,977	10.91	10.71
North Shewa	17,698	10.98	80,512	5.26	4.55
East Gojam	14,705	9.12	151,047	12.14	10.27
West Gojam	13,910	8.63	197,222	16.01	14.18
Waghimra	8,421	5.22	50,513	5.15	5.99
Awi	8,579	5.32	142,488	7.27	16.08
Oromiya	4,665	2.89	8,241	0.62	1.77
Total/Regional	161,239		1,328,235		8.24

Source: CSA, 2016 [11]

Sampling method and sample size

Before the actual survey was conducted secondary data and relevant information were collected through consulting responsible extension officers at Regional, Zonal and Woreda levels and baseline information were collected. Based on the secondary data semi-structured questionnaires were prepared and pre-tested.

In each Woreda five of the YESH project operational Kebeles were selected by the project based on their beekeeping potential and experiences in beekeeping for promotion of commercial beekeeping and these same Kebeles were selected for this study.

The sample size of inspected colonies and respondent beekeepers were determined based on sample size determination in random sampling method for infinite population, using 50% expected prevalence of bee diseases and pests and 95% confidence interval at 5% absolute precision. The numbers of hives colonies required and selected were 384 (Thrusfield, 2005) [40] using the following formula:

$$n = \frac{1.96^2 P_{exp} (1 - P_{exp}}{d^2}$$

Where: n = Required sample size
P_{exp} = Expected prevalence
d = Desired absolute precision

Accordingly a total of 384 honeybee colonies were selected for a diagnostic survey used by random sampling methods and it was distributed proportionally to each of the selected apiaries and backyards. In total, 2 zones, 2 "Woredas", 10 rural Kebeles (five Kebeles from each "Woreda") were selected purposively, and 384 beekeeperr farmers from the two "Woredas" from Burie Zuria and Awabel, respectively) were selected based on beekeeper population. First all beekeeping farmer populations were recorded in the Excel in each study Kebele and using random sampling method the study households were selected.

Methods of data collection and data sources

The data include both primary and secondary data. Direct observation and interviews were used to capture primary data. Both individual interviews and focus group discussions were employed. Secondary data was collected from Regional, Zonal and Woreda level extension offices for livestock and fisheries development. Specific study Kebeles, NGOs, and publications were used as sources of secondary information.

Semi-structured questionnaire

Semi-structured questionnaire was used to interview respondent beekeepers, followed by direct inspection of honeybee colonies. Both qualitative and quantitative data were collected such as household characteristics, common agro-chemicals used (by crops type, season of application and their effects on honeybees), honeybee health problems, major pests and predators, common cultural practices to manage honeybee health problems, potential constraints of beekeeping, prevalence/distribution and infestation rates of honeybee disease and pests. Age and family size of the respondents, amount of agro-chemicals applied and honey harvested, and numbers of colonies owned and absconded were collected as quantitative.

Key informants interview and focused group discussion

Key informants interviews covered experts, agro-chemical dealers, knowledgeable beekeepers, village elders. Focus group discussions (FGDs) were conducted at 5 sites per study Woreda, with 1 focus group discussion for each sample Kebele. The points for discussion were relative comparisons and prioritization of problems and their possible suggested or practiced solutions. Both men and women beekeepers as well as extension experts participated in the FGDs with about 8 to 12 participants in each.

Honeybee health diagnosis and monitoring of honeybee disease symptoms and pests

A single beehive and single apiary site and backyard were considered as one sample unit. Types of hive, colony status, management system, were considered as explanatory variables (risk factors), and tested whether they have an impact on occurrence of honeybee disease and parasites or not.

Honeybee hive was categorized as improved movable frame hive, intermediate beehive and traditional beehive. Honeybee colony status was categorized into weak, medium and strong colonies. Colonies were considered weak when a colony has small number of worker bees, not strong enough to defend enemies, and with small number of brood on comb (less than 2 sealed brood combs); medium strength colony is characterized as having moderate number of worker bees, defend enemies quite satisfactorily, and have 3 to 5 brood on comb; A strong colony is characterized by its numbers of worker bees, ability to strongly defend their enemies and have more than 5 comb filled with brood. Three altitude categories were considered highland (>2400 meters); Midland (1800 to 2400 meters) and lowland (1800 meters) above sea level (MoARD, 2009) [30]. Based on management site, hives were categorized as apiary (enclosure areas) or backyards (keeping honeybees with contact of village or residence house).

In order to examine the prevalence/distribution and infection/infestation rates of the onset of diseases and pests according to the activity periods of honeybees, samples were collected.

Finally, prevalence for apiary, backyard and colony levels was calculated following the protocols of (Vanenglesdorp *et al*., 2012):

$$\text{Prevalence} = \frac{\text{Number of positive cases}}{\text{Total number of sampled population}} \times 100$$

$$\text{Infection/infestation level} = \frac{\text{Number of positive bee}}{\text{Total number of sample bees}} \times 100$$

Honeybee colonies were inspected internally and externally to collect data on the health status and samples of adult honeybee were collected for further laboratory diagnosis. Records on the history and status of the colony, clinical symptoms of diseases and pests were taken.

During hive inspection the materials used and protective clothes were made clean and disinfected. Chisel and gloves were disinfected using absolute ethanol 97% to as much as possible avoid intended disease transmission from one honeybee colony to another.

Laboratory examination procedures

For diagnosis of honeybee diseases, monitoring and inspection two Woredas which were Burie Zuria "Woreda" from West Gojjam Zone and Awabel "Woreda" from East Gojjam Zone were selected. Five kebeles from each Woreda totally ten kebeles were selected and 103 honeybee colonies from Burie Zuria "Woreda" and 91 honeybee colonies from Dembecha Woreda totally 194 honeybee colonies were inspected from the three hive types (in modern apiary site of the project as well as backyard beekeeping sites) were selected randomly

Examination of *Varroa mites* and bee lice's

The study followed the standard methods for Varroa research as described by Dietemann *et al*. (2013) [21]. Samples of adult worker honeybees were collected from bee colonies in improved movable frame hives, intermediate hives and traditional bee hives. From each bee colony, 100 to 250 adult worker honeybees were brushed off from the brood comb directly into a wide mouth plastic jar. The collected adult worker honeybees were killed and preserved using 70% ethanol alcohol until delivery to the laboratory at Holeta Bee Research Center. These were then placed separate in 250 ml containers with 1% detergent-water solution (10 ml detergent in 1000 ml water) and vigorously shaken for 1 minute to dislodge *Varroa mites* and bee lice. The mites were collected filtering the solution through a ladle (8- to 12-mesh) that hold the bees back and let out the mites with the solutions. Then, wire gauze was used to hold the *Varroa mites* and bee lice back and discharge the solutions. The mesh wire gauze was turned down to white paper on which the presence/absence of the *Varroa mite* and bee lice were examined and counted.

Fig 1: Adult bee samples in plastic jar preserved with ethanol alcohol 70%

Examination of tracheal mite

Following the procedure of Sammataro *et al*., (2013) [36], samples of 20-30 adult honeybees were collected at random. The sample adult worker honeybees were preserved by adding 70% ethanol alcohol. The head and first pair of legs of honeybees were removed using scissor. Transverse-section thoracic disks were sliced and placed directly in a small dish containing 10-percent potassium hydroxide (KOH) 10 gm potassium dissolved with 90 ml distilled water. The sliced thoracic disks in KOH were heated and stirred gently near to boiling point for approximately 10 minutes and kept for 12-24 hours to dissolve the soft internal tissues and to expose trachea rings. The trachea ring sections were retrieved through filtration and washed with distilled water. The disk-trachea suspensions were examined for parts infested with *Acrapis woodi* under a dissecting microscope or stro-microscope at 10 magnification power.

Examination of nosema and amoeba diseases

As these two diseases are initiated by protozoan agents that affect the abdominal tract of adult honeybees, their sampling and diagnostic techniques are almost the same. A sample of 30-60 worker adult honeybees were collected from the hive entrance. The sample bees were collected and preserved in 70% alcohol until laboratory analysis. The abdomen of honeybees from each sample was cut using scissors. The cut abdomens were placed and grounded in mortar containing 5-10 ml distilled water until an even suspension is formed using pestle. The mortar and pestle were thoroughly cleaned before being used again. A loop of suspension was placed on microscopic slide using the sterilized loop and covered with cover slide. The suspension was examined under light microscope using 40-magnification power for the presence of *Nosema* spores and Amoeba cysts.

Observation of small hive beetle and wax moth

The occurrence and importance of honeybee pests in the study areas were determined through hive inspection and beekeeper interviews using semi-structured questionnaires. However, the larvae of small hive beetles and wax moth in the hive were checked through inspection of the beehives. Wax moth and small hive beetle larvae can be differentiated based on a number of morphological and behavioral characteristics.

The presence of small hive beetle infestation **(***Aethina tumida***)** was identified through its adult, larvae or pupae and colony examination methods as described by Neumann *et al.* (2013) [36]. Larvae of small hive beetle have pairs of prominent brownish dorsal spines on each segment with 3 pairs of anterior prologs only. Based on Ellis *et al*. (2013) [23], the larvae of wax moth has no spines, but number of setae(hairs) on each segment with 8 pairs of prologs (3 pairs, 4 pairs and 1 pair on anterior, abdominal and last segments respectively). Unlike the small hive beetles, it produces silken galleries.

Data management and statistical analysis

The collected data was stored in Microsoft Excel spreadsheets for data management. Analysis was done using SPSS software version 20. The statistical analysis used in the study varied depending on the type of variable and information obtained. Summarized data was presented in the form of tables and figures.

The questionnaire survey data was analyzed using descriptive statistics and the ranking of the different types of beekeeping constraints obtained in the study were done by using the rank index formula as described by Musa *et al*. (2006).

Rank index = sum of (7 X number of household ranked first + 6 X number of household ranked second + 5 X number of household ranked third + 4 X number of household ranked fourth + 3 X number of household ranked fifth + 2 X number of household ranked sixth + 1 X number of household ranked first) for an individual reason divided by the sum of (7 X number of household ranked first + 6 X number of household ranked second + 5 X number of household ranked third + 4 X number of household ranked fourth + 3 X number of household ranked fifth + 2 X number of household ranked sixth + 1 X number of household ranked first).

Correlation analysis was conducted to determine the relationship between *Varroa mite* load and bee population, bee lice and different risk factors. Chi-square test (x^2) was used to assess the association of the risk factors with the prevalence of *Varroa mite*. Statistical significance was set at $p<0.05$.

Result and Discussions

Major constraints of beekeeping

Respondent beekeepers pointed out different honeybee constraints affecting the beekeeping industry in their respective areas. They listed at least nine major beekeeping constraints that hinder the development of beekeeping in their areas. Accordingly, the major beekeeping constraints affecting beekeeping development in the study area in decreasing order of importance were absconding (22.8%), pests and predators (11.9%), scarcity of bee forage (11.8%), agro-chemical side effects (11.2%), drought(10.6%), lack of technical skill(poor honeybee colony management)(10.2%), honeybee diseases(9.7%), scarcity of water (8.1%) and lack of credit and high costs of improved inputs for beekeeping (3.4%) (Table 2).

The current result is in agreement with the findings of Assefa Abebe (2009) [43], Keralem Ejigu *et al*. (2009) [29], Tesega Belie (2009) [39], Workneh Abebe and Paskur (2011) [43, 44], Adeday Gidey *et al*. (2012) [1], Assemu Tesfa *et al*. (2013) [6], Nebiyu Yemane and Mesele Taye (2013) [33], Alemu Tsegaye (2015) [3, 23], Guesh Godifey (2015) [24, 26], Haftu Kelelew *et al*. (2015) [26], and, Haftu Kebede and Gezu Tadese (2014) [5, 29, 39, 42, 1, 6, 33, 3, 24, 26, 25] which reported that lack of bee forage, honeybee pests and predators and agro-chemicals are the major bottle necks of beekeeping in all regions of Ethiopia.

More over Sisay Fikru *et al.* (2015) [37] reported that major problems of honeybee in Jigjiga Zone were lack of bee forage, pests and predators, lack of water and honeybee diseases and pests have been reported.

Table 2: Reported constraints that affect the beekeeping development in west and east Gojjam zones and their relative ranks

Reported constraints	Relative degree of importance according to the respondent										Index	Over all rank
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th		
Lack of technical	0	24	5	90	32	17	22	25	93	4	0.102	6
lack of credit	0	1	19	0	0	0	7	9	14	56	0.034	9
Agro-chemical	179	60	54	2	1	16	8	19	0	0	0.112	4
Diseases	13	4	7	19	41	57	91	47	15	0	0.097	7
Pest and predator	59	75	78	23	34	62	7	2	22	0	0.119	2
Absconding	17	11	68	127	145	85	134	69	20	1	0.228	1
Drought	32	45	26	14	31	54	41	54	18	0	0.106	5
Scarcity of water	34	8	60	24	20	7	38	9	30	0	0.081	8
Scarcity of bee forage	39	127	72	47	17	22	5	29	1	0	0.118	3

Index = sum of (10*ranked 1st+ 9* ranked 2nd+8* ranked 3rd+7* ranked 4th+6* ranked 5th+5* ranked 4th+4* ranked 3th +3* ranked 2th + 2* ranked 1th) for individual constraints divided by the sum of (10*ranked 1st+ 9* ranked 2nd+8* ranked 3rd+7* ranked 4th+6* ranked 5th+5* ranked 4th+4* ranked 3th +3* ranked 2th + 2* ranked 1th) for over all constraints

Major causes of honeybee colony loss and trend of honeybee colony and honey yield

In this current research result the respondent beekeepers faced honeybee colony absconding (89.1%) due to different causes such as agrochemical poisoning, pests and predators, shortage of bee forage, unfavorable weather condition, unknown reason, honeybee diseases and others in their decreasing order of importance (Table 3). Our research result is comparable with Alemu Tsegaye (2015) [3] in Eastern Amhara the major threatening factor for honeybee colony absconding were the presence of pests and predators, agro-chemical application and lack of bee forage. The majority of respondents also indicated that their colonies showed decreasing trend, which is in line with report of Alemu Tsegaye (2015) [3] where 84.9% of beekeepers mentioned decreasing trends whereas 15.1% increasing trend of honeybee colony in Eastern Amhara and Bekele Tesfaye *et al.* (2017) [9] reported in Bale Zone 72.6% of beekeepers responded decreasing trends. Generally, most respondents reported that honey yield is decreasing (79.9%), while some mentioned increasing trend (15.9%) and few said no change (3.1%) (Table 3). This result in agreement with Tesege Belie (2009) [39] in Burie Woreda reported honey production trend was decreasing.

Table 3: Reported frequencies of honeybee colony loss and their causes and trends of honeybee colony and honey yield in west and east Gojjam zones

Description	Response	Frequency	%
Did you face honeybee colony absconding	Yes	342	89.1
	No	28	7.3
	Total	370	96.4
Causes for honeybee colony absconding	Shortage of bee forages	39	10.2
	Pest and predators	99	25.8
	Diseases and parasites	10	2.6
	Unfavorable weather	28	7.3
	Agrochemicals poisoning	132	34.4
	Do not known	23	6.0
	others	8	2.1
	2*5	2	0.5
	Total	341	88.9
Honeybee colony trends	Decrease	307	79.9
	Increase	61	15.9
	No change	12	3.1
	Total	380	98.9
Honey yield trends	Decrease	304	79.2
	Increase	75	19.5
	Total	379	98.7

2*5 = pest and predator and agro-chemical poisoning together

Honeybee pests and predators

Respondents listed out prevalent pests and predators in their respective areas. After having identified the major pests, honeybee keeper farmers were requested to rank them in order of their importance and the result indicated that Ants (17.4%), Wax moth (16.7%), Bee-eater birds (16%), praying mantis (Enziz in common name) (12%), Honey badger (12%), bee lice and parasitic mites (10.9%), small hive beetles (10.6%), wasps (4.8%), snake (0.2%) and Lizards (0.1%) were the most harmful pests and predators in order of decreasing importance (Table 4 and Fig 3). In Ethiopia, more than 15 honeybee pests were identified and recorded (Desalegn Begna 2001, Desalegn Begna and Amssalu Bezabeh, 2001, Desalegn Begna and Yosef Kebede, 2005, Desalegn Begna and Amssalu Bezabeh, 2006) [13, 14, 20, 19].

In the present study, ants were identified to be the first ranked pest in the study area. Similar results were reported from different regions of Ethiopia such as Addis Abeba (Desalegn Begna and Yosef Kebede, 2005) [20], Burie Zuria Woreda (Tesega Belie, 2009) [39], Keffa, Shako and Bench- Maji zone (Awraris Getachew *et al*., 2012) [7], Central Ethiopia (Workneh Abebe, 2011) [43] and Gomma district (Challa Kinati *et al*, 2013).

The presence of the pests and predators such as: honey badger, ants, wax moth bee-eater birds, spiders and lizards were reported in Tigray National Regional State by Adeday Gidey *et al*. (2012) [1], Guesh Godifey (2015) [26] and Haftu Kelelew *et al*. (2015) [1, 24, 26]. It was also reported from the eastern parts of the Amhara Region by Alemu Tsegaye (2015) [39]. These pests and predators were also reported from Burie Zuria Woreda by Tesega Belie (2009) [39], Gomma Woreda by Challa Kinati *et al*. (2013), and from Walmara district by Dabessa Jatema and Belay Abebe (2015) [12]. Adeday Gidey *et al*. (2012) [1], Guesh Godifey (2015), Haftu Kelelew *et al*. (2015) and Alemu Tsegaye (2015) [1, 24, 26, 3] listed out ants, wax moth, and bee-eater bird pests as the top ranked pest of honeybees.

According to Kajobe *et al*. (2009) [28], at least 12 pests and predators that attack honeybees and the hives were documented in Uganda. Similarly, honeybee pests such as ant, wax moth and spiders are major constraints for beekeeping industry in Nigeria (Akinwande *et al*., 2013) [2].

Table 4: Reported frequency of major pests and predators of honeybee in west and east Gojjam zones and their relative ranks

Honeybee pests and predators	Relative degree of importance according to the respondent										Over all rank
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	Index	
Ant	62	123	55	58	53	9	3	0	0	0.174	1
Wax moth	196	63	33	15	38	3	0	0	0	0.167	2
Bee lice	9	11	42	51	83	25	7	0	0	0.109	6
Small hive beetle	1	6	29	33	24	102	22	4	1	0.106	7
Wasp	0	0	0	3	4	2	25	60	6	0.048	8
Praying mantis	30	19	59	49	18	11	11	1	52	0.12	4
Lizards	0	0	0	1	0	0	0	1	0	0.001	10
Snake	0	0	0		3	0	1	1	0	0.002	9
Hamagote/honey badger	10	10	52	43	51	29	14	38	2	0.12	5
Birds	37	69	53	63	16	27	59	9	0	0.16	3

Index = sum of (9*ranked 1st+ 8* ranked 2nd+7* ranked 3rd+6* ranked 4th+5* ranked 5th+4* ranked 3th+3* ranked 2th +2* ranked 1th) for individual pests and predators divided by the sum of (9*ranked 1st+ 8* ranked 2nd+7* ranked 3rd+6* ranked 5th+5* ranked 4th+4* ranked 3th+3* ranked 2th +2* ranked 1th + 1*) for over all pests and predator

Honeybee diseases

According to this study 22.7% of the respondents have observed honeybee diseases in their colony the rest 71.6% of the respondents did not identify honeybee diseases in their colonies. Some respondents did not have any idea about honeybee diseases, but they have observed dead honeybees around hive entrance. A situation called “Mushen” caused by “Abrik” recurs during summer season, this is justify that might be due to Nosema disease and chalk brood. They also observed wax moth infestation, which is locally known as “Azebater”. Shortage or lack of technical training and lack of experience on honeybee diseases are believed to explain the rather low frequencies reported. This research result in line with Tesege Belie (2009) [39] reported in Burie Woreda beekeepers didn’t have an idea about honeybee diseases and their causes (Table 5).

Apparently, 37.5% of the respondents have awareness about honeybee disease transmission from infected colonies to healthy ones and 59.6% of the respondents do not have awareness about honeybee disease transmission; some even believe that honeybees do not get affected by diseases. Informed respondent beekeepers know different honeybee disease transmission mechanisms, such as unclean beekeeping materials or equipment 14.8%, robbing1.3%, common feeding 0.8%, and beekeeper him/herself (6.3%) respectively (Table 5).

Beekeepers also reported that very aggressive behavior of honeybee colonies (72.1%) confers more defensive capability to diseases and pest attack compared with aggressive (26.6%) and docile colonies, justify that aggressive behavior colonies might have more hygienic behaviors of dead broods which leads to disease agents and attacking abilities of pests. All of the respondents believed that only weak colonies get infected by honeybee diseases and attacked by pests than medium and strong colonies (Table 5). This might be implies that beekeepers knowledge and experiences is limited on honeybee diseases and pests effect on honeybee colony.

Table 5: Frequency of reported occurrence of honeybee diseases in west and east Gojjam zones

Description	Response	Frequency	%
Status of honeybee disease in your colony	No	275	71.6
	Yes	87	22.7
Awareness of honeybee disease	No	229	59.6
	Yes	144	37.5

Disease transmission mechanism	Materials	57	14.8
	Robbing	5	1.3
	Common feeding	3	0.8
	Beekeeper	24	6.3
Defensive behavior of honeybee colony against disease and pest attack	Aggressive	106	27.6
	Very aggressive	277	72.1
colony status infected by pest and disease/any agents	Weak colony	384	100.0
	Medium colony	-	
	Strong colony	-	

Fig 2: Observed wax moth infestation in traditional hive (A) and movable frame hive (B) at Burie Zuria and Awabel Woredas

Laboratory diagnosis of honeybee disease and parasitic mites

The laboratory investigation has made possible of identification and confirmation of the major honeybee parasites *varroa mites*, bee lice and tracheal mites and adult honeybee diseases Nosema and Amoeba.

Occurrence and prevalence of *Varroa mites*

From the total 194 colonies examined 103 from Burie and 91 Awabel *woredas* for the presence of *varroa mite*, the laboratory diagnosis has confirmed that 152 of them (78.35%) had *varroa mites* in them. The present result was found to be slightly lower than previous research findings of *varroa mite* prevalence by Desalegn Begna (2014) [18] of 82% in Tigray Region; Alemu Tsegaye (2015) [3] also reported 85.9% prevalence in the eastern parts of the Amhara Region. However, lower prevalence was reported by Guesh Godifey (2015) [24] which is 62.1% during honey flow and 53.4% during dearth periods. Different African countries reported different result on *varroa mite* prevalence: 78.6% in Nigeria (Akinwande *et al*., 2013) [2], 100% in South Africa (Strauss *et al*., 2013) [38], 83% in Kenya (Muli *et al.*, 2014) [31], and 92% in Tanzania (Mumbi *et al*., 2014) [32].

In our study, a higher varroa prevalence of 86.9% was observed in apiary colony management system compared with 71.8% for backyard colony management, and the difference was statistically significant (χ^2=6.391; P<0.01) (Table 6). This might be associated with the confinement of colonies, close transmission between colonies and the introduction of colonies from unknown sources to the movable frame hives. Regarding the hive type *varroa mite* prevalence was higher in intermediate (88.89%) and movable hive types (85.89%) than in traditional hives (71.96%) (Table 6). This current research result was in line with the findings of Alemu Tsegaye (2015) [3] who reported 94.2%, 84.8% and 79.85% in movable frame hive, intermediate and traditional hives, respectively, in the eastern parts of the Amhara Region. In contrast Guesh Gudifey (2015) [24] reported in Tigray Region that *varroa mite* prevalence was high in traditional hives than in movable frame hives (68% versus 58.8%). In relation to colony strength, *varroa* prevalence was almost similar between strong and weak colonies (80 and, 81%), but slightly lower in medium strength colonies (70.28%) but the differences were not statistically significant (P>0.05). Statistically significant (χ^2=13.793 ; P<0.001) difference was observed in *varroa mite* prevalence between the study locations 90.12% in Awabel *Woreda* in East Gojjam Zone compared with 68.93% of Burie Zuria Woreda located in West Gojjam Zone (Table 6 and fig 4). This result variation might be associated with agro ecology difference, Awabel Woreda near to highland whereas Burie Zuria Woreda as mid land.

Table 6: Prevalence of varroa mite and the different risk factors in Awabel and Burie Woredas

Risk factors	Samples			χ^2	*P*- value
	Total (n)	Positive (n)	Positive (%)		
Colony management					
Backyard	110	79	71.81	6.391	0.011**
Apiary	84	73	86.9		
Hive type					
Traditional	107	77	71.96	5.782	0.056
Intermediate	9	8	88.89		
Improved frame	78	67	85.89		
Colony strength					
Strong	120	96	80	1.779	0.411

Medium	37	26	70.28		
Weak	37	30	81.08		
Sample *woreda*					
Awabel	91	82	90.12	13.793	0.000***
Burie Zuria	103	70	68.93		
Total	194	152	78.35		

Fig 3: *Varroa mites* identified from the study area

Infestation rate of *varroa mites*

Observed *varroa mite* infestation rates of adult bees in apiaries have slightly higher (3.15±0.32) rates than those of the backyard (2.17±0.22), this result variation might be due to the confinements of more colonies in apiary site. Such rates were also calculated by colony strength (2.8±0.45, 1.96±0.32 and 2.72±0.25) for weak, medium and strong colonies, respectively (Table 13). Higher *varroa* infestation rates were observed from intermediate hives (4.28±1.23) than in movable frame hives (2.95±0.32) and traditional hives (2.18±0.22), might be due to favorability of bee hive types for varroa spreading. These rates are similar to those reported by Alemu Tsegaye (2015) who reported higher *varroa* infestation rates from intermediate (5.12±0.55) than from movable frame hives (4.98±0.45) and traditional hives (4.02±0.34). In the present study higher infestation rate was observed in Awabel than Burie Zuria *Woreda* (3.40±0.31versus1.88±0.21) (Table 7). This variation of infestations might be due to agro-ecology difference.

Table 7: Observed *Varroa mite* infestation rates by, management, colony strength hive type and location

Variable	Adult bees sampled				Number of varroa mites/sample			Infestation rate/sample of bees		
	N	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max
Colony management										
Back yard	110	93.83±3.28	33	228	2.03±0.24	0	18	2.17±0.22	0	10
Apiary	84	107.32±3.67	33	172	3.25±0.32	0	14	3.15±0.32	0	13
Colony strength										
Medium	37	88.16±4.10	38	140	1.67±0.31	0	8	1.96±0.32	0	8
Strong	120	109.58±3.06	33	228	2.85±0.26	0	14	2.72±0.25	0	11
Weak	37	79.05±5.67	33	172	2.41±0.52	0	18	2.8±0.45	0	13
Hive type										
Improved frame hive	78	108.91±3.37	60	171	3.14±0.35	0	14	2.95±0.32	0	11
Intermediate hive	9	98.44±17.72	36	172	4.44±1.81	0	18	4.28±1.23	0	10
Traditional hive	107	93.04±3.37	33	228	1.97±0.19	0	9	2.18±0.22	0	13
Sample Woreda										
Awabel	91	107.42±3.68	33	228	3.51±0.31	0	14	3.40±0.31	0	13
Burie	103	92.83±3.24	36	189	1.72±0.23	0	18	1.88±0.21	0	10

Correlation of *varroa mite* infestation with different risk factors

Infestation levels were observed to have a significant positive correlation with number of sampled bees (r=-0.311, p=0.000) and positive correlation with the risk factor of hive types (r=0.209, p= 0.003) (Table 8).

Table 8: Correlations of *Varroa mite* load level with some risk factors in Awabel and Burie "Woredas"

		NB	NVM	PVM	HT	CM	CS
NB	R	1	.311**	.036	.221**	-.004	-.342**
	P		.000	.620	.002	.952	.000
NVM	R		1	.899**	.209**	-.122	-.090
	P			.000	.003	.089	.214
PVM	R			1	.147*	-.125	-.021
	P				.041	.082	.773
HT	R				1	-.335**	-.037
	P					.000	.606
CM	R					1	-.026
	P						.719

CS	R						1
	P						

Prevalence of bee lice (*Braula coeca*)

From the total colonies examined for the presence of bee lice, the laboratory diagnosis confirmed that 22 (11.34%) were found to be infested with bee lice (Table 9 & fig 5). This result was lower than the rate reported by Gizachew Gemechu *et al*. (2013) [23], who reported 42% of colonies infested with bee lice at Holeta and its surrounding areas. Alemu Tsegaye (2015) [3] reported from eastern Amhara reported 30.7% infestation rate and Guesh Godifey (2015) [24] reported in Tigray Region 27.5% and 5.73% during honey flow and dry seasons, respectively. However, the current finding was found to be higher than the *Braula coeca* prevalence reported by Adeday Gidey *et al*. (2012) [1] which was 5.5% in the adult honeybee in Wuqro district, Tigray region.

We have observed that bee lice prevalence was slightly higher in backyard beekeeping management system (11.82%) that in modern apiaries (10.71%). When we see hive types used by beekeepers and the bee lice prevalence was higher (12.82%) in movable frame hives that in intermediate (11.11%) and more so (10.28%) than in traditional hive types (Table 9). Alemu Tsegaye (2015) [3] reported that bee lice prevalence was higher in movable frame hives (46.5%) than in intermediate hives (31.9%) and traditional (17%). contrary to our result Gizachew Gemechu *et al.* (2013) have reported that the highest bee lice prevalence (48.5%) was observed in traditional hives at Holleta and Guesh Godifey (2015) reported 29% bee lice prevalence in traditional bee hives. There was also difference in bee lice prevalence in movable frame hives between Woredas: 12.09% in Awabel and 10.68% in Burie Zuria Woreda, perhaps due to differences in altitude, with Awabel Woreda having a higher average altitude than Burie Zuria Woreda. However, the difference in prevalence of bee lice was not statistically significant among risk factors (*P*>0.05) (Table 9).

Table 9: Observed prevalence of bee lice by different risk factors in Awabel and Burie Woredas

Risk factors		Samples		χ^2	*P*- value
	Total (n)	**Positive (n)**	**Positive (%)**		
		Colony management			
Backyard	110	13	11.82	0.085	0.810
Apiary	84	9	10.71		
Hive type					
Traditional	107	11	10.28	0.290	0.865
Intermediate	9	1	11.11		
Improved frame	78	10	12.82		
		Colony strength			
Strong	120	16	13.33	1.781	0.411
Medium	37	2	5.41		
Weak	37	4	10.81		
		Sample Woreda			
Awabel	91	11	12.09	0.095	0.758
Burie	103	11	10.68		
Total	194	22	11.34		

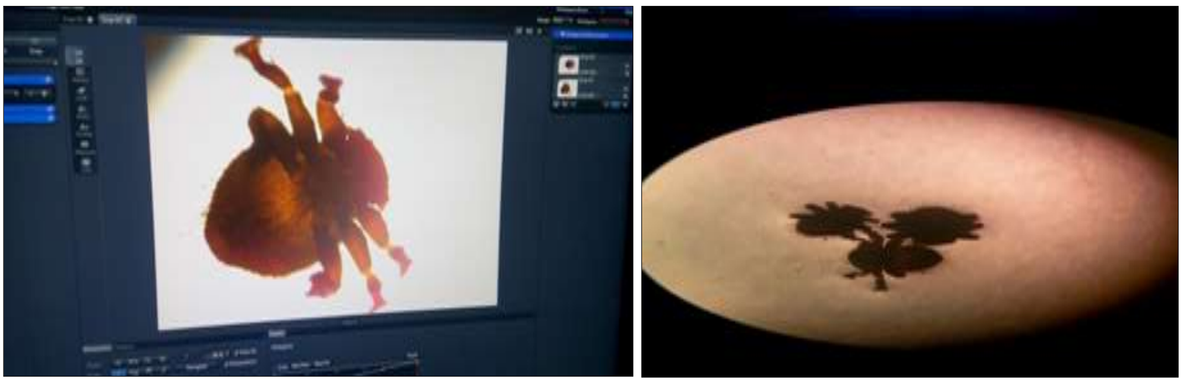

Fig 5: Bee lice observed in the study area

Prevalence of Nosema disease

Diagnosis Diagnosis made on honeybees sampled from the study area revealed prevalence of 51.03% (99/194) *Nosema* infection (Table 10 & Fig 6). The laboratory diagnostic result also confirmed that the prevalence of *Nosema apis* in apiary colony management was 58.33% which was higher than backyard colony management of 45.45% (Table 10), might be due to confinements of more colonies in apiary site leads to contamination through drifting and robbing. In case of hive types *Nosema apis* prevalence was higher in movable frame hive followed by intermediate and traditional hive types (62.82%, 44.44% and 42.99%, respectively) and this difference was statistically significant (χ^2=7.263; *P*<0.01) (Table 10), justify that might be hive type difference. This result contradicts the findings of Guesh Godifey (2015) [24] who reported that *Nosema apis* was higher in traditional hives (43%) than in movable frame hives (29.6%), but Qertel (1967) cited by Guesh Godifey (2015) [24] stated that colonies of honey bees that are opened and manipulated at regular intervals showed more infection with *Nosema apis*. Regarding to colony strength *Nosema apis* prevalence was 54.11% in strong colony and 45.95% in both medium and weak colonies (Table10). Moreover, *Nosema apis* prevalence was higher in Awabel *Woreda* (59.34%) than in Burie *Woreda* (43.69%) (Table 10). This current study result is in line with that of Guesh Godifey (2015) that *Nosema apis* prevalence was higher in highland (50%) areas than in midlands (31.6%) and even more so in lowlands (3.2), and this difference was statistically significant (χ^2=4.736; P<0.01).

Table 10: Observed prevalence of Nosema disease and its associated risk factors in Awabel and Burie Woredas

Risk factors	Samples			χ^2	*P*-value
	Total (n)	**Positive (n)**	**Positive (%)**		
Colony management/site/					
Backyard	110	50	45.45	0.037	0.848
Apiary	84	49	58.33		
Hive type					
Traditional	107	46	42.99	7.263	0.026**
Intermediate	9	4	44.44		
Improved frame	78	49	62.82		
Colony strength					
Strong	120	65	54.17	1.238	0.539
Medium	37	17	45.95		
Weak	37	17	45.95		
Sample Woreda					
Awabel	91	54	59.34	4.736	0.030**
Burie Zuria	103	45	43.69		
Total	194	99	51.03		

Fig 6: Observed Nosema (bean shape) and amoeba (circle in shape and small in size) in the study area

Prevalence of *Amoeba* disease (*Malpighamoeba mellificae)*

Amoeba (*Malpighamoeba mellificae)* prevalence in the study *Woredas* was almost all of the samples were positive 98.97% (192/194). The differences in prevalence among the hive types was statistically significant (χ^2=10.126; P=0.006) (Table 11) where traditional hive types are more affected. This might be related with internal inspection frequency, hence traditional hive which is not suitable for internal inspection.

Almost honeybee colonies at all status were affected similarly with Amoeba disease (*Malpighamoeba mellificae).* It was also observed that 100% of the hive colonies in Awabel and 98.02% in Burie Zuria *Woreda* were infected with Amoeba disease (*Malpighamoeba mellificae).* This shows as Amoeba disease is more prevalence in all aspects than the other honeybee diseases even if Nosema and Amoeba diseases are more prevalence in rainy season.

Table 11: Observed prevalence of amoeba by different risk factors in Awabel and Burie Zuria Woredas

Risk factors	Samples			χ^2	*P*-value
	Total (n)	**Positive (n)**	**Positive (%)**		
Colony management					
Backyard	110	109	99.09	0.037	0.848
Apiary	84	83	98.81		
Hive type					
Traditional	107	107	100	10.126	0.006***
Intermediate	9	8	88.89		
Improved frame hive	78	77	98.72		
Colony strength					
Strong	120	119	99.17	1.445	0.486
Medium	37	37	100		
Weak	37	36	97.29		

Sample Woreda					
Awabel	91	91	100	1.785	0.181
Burie Zuria	103	101	98.06		
Total	194	192	98.97		

Prevalence of Acarine mites

Laboratory test was carried out for the presence of *Acarine mites* that enter and block the respiratory systems of the adult bees. In all samples tested, there was no positive result that would indicate the presence of the *Acarine mite*. Similar result was reported by Alemu Tsegaye (2015) [3] in Eastern Amhara Regional State and Guesh Godifey (2015) [24] in Tigray Regional State.

Fig 4: Sample acarine under observation through stro microscope, (B) and observed acarine sample and free from Acarine mite (A)

Conclusion

Beekeeping is an important agricultural income generating activity in the study area. The major beekeeping constraints affecting beekeeping development in the study area were pests, predators and honeybee diseases.

Major honeybee pests and predators detected in the study area include ants, Wax moth, Bee-eater birds, praying mantis (Enziz in common name), honey badger, bee lice and parasitic mites, small hive beetles, wasps, snake and Lizards. These pests and predators were identified as the major causes of absconding (25.8%), dwindling and honey yield loss. In most cases wax moth, ants and bee eater birds were the most destructive pests and predators for the honeybees.

Laboratory analysis of bee colony samples revealed that *Varroa mites*, *bee lice*, *Nosema* and *Amoeba* are prevalent in the study area. They have different degree of prevalence as affected by various risk factors like colony management system, hive types, colony status and study location. Tracheal mites were not found throughout the study period.

Based on findings of this study, the following recommendations are put forward:

- It is essential to capacitate beekeepers in terms of technical knowledge and skills to better manage known honeybee pests and diseases.
- The presence of *Varroa mite* in the country in general and the study area in particular is now confirmed. However, infected honeybee colonies appear to be producing well, which may be that they have developed some level of tolerance. This needs further research, especially on whether there indeed in natural tolerance level already developed in the colonies.
- Further study on seasonal prevalence and economic importance of honeybee diseases and pests is warranted. Long term colony monitoring studies are needed for thorough understanding of these problems and suggest practical solutions.

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