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Incidence and Infestation Rate of Varroa Mite (Varroa Destructor) On Local Honey Bee Colony in Metema District, North Western, Amhara Regional State, Ethiopia

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GRADUATE PROGRAM

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MSc Thesis

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THESIS APPROVAL SHEET

As members of the Board of Examiners of the Masters of Sciences (M.Sc.) thesis open defence examination, we have read and evaluated this thesis prepared by **Mr. Gashaw Wagnew** entitled: /**Incidence and Infestation Rate of Varroa Mite (*Varroa destructor*) on Local Honey Bee Colony in Metema District, North Western ,Amhara Regional State, Ethiopia/.** We hereby certify that, the thesis is accepted for fulfilling the requirement for the award of the degree of Master of Sciences (M.Sc.) in Apiculture.

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iii

DECLARATION

This is to certify that this thesis entitled /**Incidence and Infestation Rate of Varroa Mite (*Varroa destructor*) on Local Honey Bee Colony in Metema District, North Western ,Amhara Regional State, Ethiopia**/ submitted in partial fulfilment of the requirements for the award of the degree of Master of Sciences in Apiculture to the Graduate Program of College of Agriculture and Environmental Sciences, Bahir Dar University by **Mr. Gashaw Wagnew(ID.NO.BDU1100775)** is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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iv

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DEDICATION

This thesis is dedicated to my mother **W/ro Amarech Kelekay** and to my wife **W/ro Felegush Baytekus** and also our child **Meskerem Gashaw** for their unlimited sacrifice, understandings and support they provided to me during my study.

LIST OF ABBREVIATIONS

ABPV	Acute Bee Paralysis Virus
BQCV	Black Queen Cell Virus
CCD	Colony Collapse Disorder
CSA	Central Statistical Agency
DWV	Deformed Wing Virus
FERA	Food and Environment Research Agency
IAPV	Israeli Acute Paralysis
IBRA	International Bee Research Association
ILRI	International Livestock Research Institute
IPNS	Integrated Pest Management System
KBV	Kashmir Bee Virus
M.a.s.l	Meter above sea level
MAAREC	Mid-Atlantic Apicultural Research and Consortium
MOARD	Ministry of Agriculture and Rural Development
MWOLF	Metema Woreda Livestock and Fishery Office
NBU	National Bee Unit
No	Number
OIE	Organization International Epizootic
RNA	Ribose Nucleic Acid
SE	Standard Error
SPSS	Statistical Package for Social Science
USA	United State of America
WOARD	Woreda Agriculture and Rural Development Office

"Incidence and Infestation Rate of Varroa Mite (Varroa destructor) on Local Honey Bee Colony in Metema District, North Western, Amhara Regional State, Ethiopia"

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ABSTRACT

This study was conducted in Metema district, North Western, Amhara Regional State between October 2019 to March 2020. The aim of this study was to identify the incidence of Varroa mite in local honey bee colony and to determine Varroa mite infestation rate in local honey bee colony. The study was carried out in four randomly selected "Kebeles" (Meka, Lemlem Terara, Kumere Aftiti and Gubay Jejibet) of Metema district based on their potential. Accordingly, a total of 107beekeepers were randomly selected and interviewed with semi-structured questionnaire, field observation, group focused discussion and key informants were used to collect the primary data. From each "Kebeles"24 honey bee colonies were inspected from 2 apiaries site (8 bee colonies from the hive types and 2 apiaries site from each "Kebeles") 8 apiaries site and 96 honey bee colonies were diagnosed from adult bees and brood bees and the data was analyzed using descriptive statistics including mean, frequency, standard division in forms tabular, graph using SPSS version 23 software. An average of 291 ± 10 and 98.25 ± 2.06wereexamined of adult bees and brood cells were opened from each bee colony an average of 10 ± 2 (ranging from 9-12) and 8.3 ±2.872 (range from 6-12) varroa mites were detected respectively .The result also showed that the prevalence of Varroa destructor was 82(85.42%) in the brood and 71(73.6%) in the adult honey bees respectively positively. The prevalence of mite infestation in the brood and adult bees of the four selected "Kebeles" were 79.17%, 83.33%at Meka, 100%, 79.17%at Lemlem terara, 75.00%, 62.50%at Kumer Aftiti and 87.50%, 70.83% at Gubay Jejibet respectively. The high varroa mite infestation on both brood and adult bees at all the four selected "Kebeles "need to be consider huge threat to beekeeping practice and honey production as well as crop production of the area unless an appropriate management practices is followed to minimize the well-known weakening and devastating effect of varroa mite on the honey bee colonies, the honey production and crop pollination dependent on the honey bees.

Key words: *Beekeeping, Bee Colony, Incidence rate, Infestation rate, Varroa destructor*

TABLE OF CONTENTS

LIST OF TABLES

Table page

LISTOF FIGURES

Figures page

LISTOF APPENDIX TABLES

Appendix Table Page

LIST OF APPENDIX FIGURES

Chapter 1.INTRUDUCTION

1.1. Back ground and Justification

The contribution of honey bees to agriculture production (Gallia *et al.*,2009),food security(Archer *et al*., 2014 and Chemurot2017) nutrition, income in households(Muli *et al*.,2014) and ecosystem services (Tantillo *et al*., 2015)is siginificat.However ,beekeepers are experiencing high colony losses ,especially in developed country (Smith *et al*.,2013) which are attributed to many interacting factors including honey bee diseases (Smith *et al.*,2013),pests(Smith *et al*.,2013),pesticides (Vanengelsdorp *et al*., 2012) and nutritional stress(Vanengelsdorp *et al* .,2008 and Henry *et al*.,2012).Of these, the ectoparasitic mite *Varroa destructor* has been assigned as one of the most important causal factors (VanEngelsdorp et *al.*,2012) and for decades beekeepers from Europe and USA mainly rely on treatment with acaricides to control mite infestation levels (Rinkevich *et al*.,2017). The presence of varroa mite has been confirmed in many Africa countries, including Ethiopia (Pirk *et al.*, 2016.).

Varro mites (*Varroa species)* reproduce in the cell of developing honey bees. They feed on the haemolymph of developing and adult bees, resulting in transmission of secondary diseases that reduces the lifespan of infested individuals (Dainat *et al*., 2011). The mites shifted from their natural hosts, the Eastern honey bees *Apis cerana* to the Western honey bees *Apis mellifera*, about 70 years ago after *Apis mellifera* was introduced into the native range of *Apis cerana* (Rosenkranz *et al*., 2010).The commercial transportation of colonies spreads has resulted in the cosmopolitan distribution of *Varroa destructor*, which has dramatic consequences for both managed and wild population of *Apis mellifera*. *Varroa jacobsoni* has relatively minor effects on colonies, its natural host of *Apis cerana* at least in the part because the varroa mite can only reproduces when male brood is presents. In contrast *Varroa destructor* can reproduce on both male and female brood of *Apis mellifera*, thus attaining a longer reproductive season and larger mite population (Rosenkranz *et al*., 2010).

With larger numbers of varroa mites in colonies, a greater proportion of bees and larvae are affected. Without treatment, a colony of *Apis mellifera* infested with *Varroa destructor* dies within one to three years (Fries *et al*., 2006).Whereas *Apis cerana* colony are able to them survive infestation by varroa mites without apparent damage. *Varroa destructor* is considered to be the major pest of honey bees since it spread to *Apis mellifera.* Recent studies have confirmed its substantial contribution to honey bees loss across the Northern hemisphere (Vanengelsdorp, 2011).This parasite was first reported in South Africa in 1997(Allsopp et *al.,* 1997 and Rinkevich et *al*., 2017) and later in 2009 in Kenya, Uganda and Ghana (Martin and Kryger, 2002)and Ethiopia in 2010(Desalegn Begna, 2014). However, the understanding on the varroa mite strain, its seasonal dynamics and effects on local bees and their products in Ethiopia remain blurred. Therefore, given the wide spread of the varroa mite in most beekeeping area of the country, it is paramount importance to investigate the plausible effects of this mites have both on the life and products of local honey bees.

Recently, report on the unknown honey bee colony death and dwindling has been received from Amhara regional state bureau of agriculture in the different districts. Based on the received case report, extensive diagnostic surveillances was conducted in four selected "Kebeles "of Metema district to identify the plausible causes behind the honey bee colonies death and dwindling in Metema district of North Western, Amhara Regional State. In general, this action research aims at collecting of the data and providing analytical information that guide government organization in the formulation of public policies, institutions and infrastructural development affecting the sub-sectors, and the introduction of new honey production and processing of technologies. The research also aims to assist the government and non-government organization to design intervention strategies to help farmer and other business groups in meeting the increased demand for food and address the challenges existing across the value chain of honey bee products that hinder smallholder producers and business groups from maintaining and expanding their market bases to increase their income from honey production.

1.2. Statement of the problem

Most honey bee research considers the ectoparasitic mite (*Varroa destructor*) to be the most damaging enemy of the honey bee. It has been recently identified as one of the major factor responsible for colony losses worldwide (Brodschnieder *et al.*, 2010 and Nazzi *et al.,* 2012).Both the development of new and innovative control methods against the mite and further studies on the complex interaction with the honey bee should be a priority in bee health research

(Dietemann *et al*., 2012).When first investigation report for the presence of Varroa mite(*Varroa destructor*) as one of the potential honey bee pests, was published by (Desalegn Begna ,2014) who reported the overall prevalence of 82% in Tigray Region. Also, nation-wide diagnostic survey conducted from 2008-2010 showed that there was wide scale distribution of Varro mite in most areas of eastern parts of Amhara Region (Abebe Jenberie *et al.*, 2010, unpublished).

Based on this report, except a few places, almost all areas starting from Abergele district (Waghimra Zone) up to Kalu district in (South Wollo Zone), Varroa mites were observed. On the other hand, during that time, some areas like Desse Zuria, Legambo districts and some localities in some districts were free from Varroa mites (*Varroa destructor)*. However, varroa mite free areas are not continuous and might not be guarantee to be free from the disease for long time. In addition to recent years, there were some complaints about the colonies number decline and low productivity of honey bee colonies these areas. More specifically potential threats have incited a great concern in the investigation of the problem in order to come up with the practicable measures and techniques against these potential threats. In these cases, assessment and the identification of the occurrence of harmful honey bee diseases, pests and honey bee poisoning has been recommended as a key step of a plan targeting exploitation of opportunities from the sector (Adeday Gidey *et al*., 2012).

Amhara Region, as one of the potential regions in the country, has a huge honey bee colony resource potential. The region contributes 23% of the honey bee colonies and 22.8% of the total honey production in the country (CSA, 2014/15).There are a lot of resources in the honey bee flora, and honey bee colony. But use of such the potential resources remained to be minimal in many aspects, due to many challenges. The honey bee diseases, pests and predators are reported to be among the challenges in beekeeping sector. So, this study aimed to identify Varroa mite (*Varroa destructor*) infestation rate and its incidence rate on local honey bees. Failure to detect and recognize early effects has been witnessed to bring about a decreased of productivity and even important colony losses. So it’s known as North Western in Metema district in particular is known for its potential for beekeeping production

1.3. Objective

1.2.1. General Objective

To determined incidence and infestation rate of Varroa mite on local honey bee colony of Metema district

1.3.2. Specific Objective

- To identify the incidence of Varroa mite in local honey bee colony
- To determine Varroa mite infestation rate in local honey bee colony

1.4. Research Questions

1. Does Varroa mite (*Varroa destructor*) occur on local honey bee colony of Metema district?

2. What is the current infestation rate of varroa mite on local honey bee colony of Metema district?

Chapter 2: LITERATURE REVIEW

Honey bee health as the ultimate subject of research and development of beekeeping in nearly all beekeeping regions have been studied from multidimensional perspectives. In this section, different topics about honey bee health are reviewed. The major topics and concepts are varroa mite (*Varroa destructor*), Taxonomy, geographical distribution, transmission, life cycle of varroa mite **,**effects and clinical manifestations, effects on the individual honey bees, effect on the colonies, diagnosis , alcohol washing and economical impact of varroa mites.

2.1. Varroa Mite

Varroa mites are ecto-parasite that feed on the haemolymph of immature and adult honey bees (Ellis and Nalen, 2010). The genus of varroa mite including two species, *Varroa destructor* and *varroa jacobsoni* (OIE ,2008).However, *Varroa destructor is* the only species of economic impacted in contrast to *Apis cerana* which can support population (Ellis and Nalen,2010).

2.2. Varroa Destructor

Could be the main reason for recent decline of honey bee colonies (Kevan *et al., 2007*) it cause disease of honey bees called *varroasis* (Carreck *et al*., 2010; Dahle, 2010; Martin *et al., 2010)* which appears from autumn to early spring during the overwintering phase. It causes general weakening and often complete losses .It is also a vector of number of viruses which affect honey bees' health and shorten the live of infected bees under certain condition. *Varroa destructor* does not have any free living life stage and complete all on honey bees. When a bee has been infested by this ecto –parasite, it take the longer time to return or even does not return to the colony (Okosum, 2013). The *Varroa destructor* mite has an impact on the bee's immune system and on the susceptibility of honey bee toward pathogens (Foley *et al*., 2005*).*

Varroa destructor has been found to be responsible for colony loss especially in combination with virus infestation (Kielmanowicz *et al*., 2015). So *Varroa destructor* is responsible for the colony losses of *Apis –mellifera*. According to (Evans *et* al., 2009), 20 positive -strand RNA viruses infect honey bees which are mainly related to the families of Dicistroviridae and Iflaviridae. Until the introduction of honey bees mite ,*Varroa destructor* ; the viral pathogens were generally considered harmless (Genersch ,2010) but later on , viruses have been suspected as casual agents of colony losses (Neumann and Carreck,2010 and Cepero *et al*.,2014).It appears that varroa acts both as disseminator and activator of some viruses like acute bee paralysis (ABPV),Kashmir bee virus (KBV), and Israeli acute paralysis virus(IAPV) , Deformed wing virus (DWV) is a member of the Iflaviridae family and appears not only to be transmitted by varroa mite but also to replicate within the mite(Genersch *et al*.,2010). Deformed wing virus mainly causes symptom less infection and is transmitted vertically through drones and queens or horizontal through larval food (Robin *et al*., 2010).

When transmitted to pupae through *Varroa destructor* , it causes infection resulting mainly deformed wing with other effects like shortened and bloated abdomen (Kielmanowicz *et al* .,2015)leading to the death of bees within less than 67 hour after emergence (Cox-Foster *et al.*,2007).Deformed wing virus has been reported as a potential cause for colony losses because it can act independently of *Varroa destructor* (High *et al.,2009).*Di Prisco *et al.*(2011) showed that the low temperature of winter increase the virus infection in honey bees and that the severity of DWV infection was positively correlated with *Varroa destructor* density. They also showed that host condition are important on outcome of DWV showing honey bees mortality rate .Israeli Acute Paralysis Virus has been identified as a marker or secondary agent of CCD(Evans *et al*.,2009) and anti-viral treatment using IAPV-specific RNA it was able to silence IAPV and to reduce the symptom of CCD(Maori *et al*.,2009).

Israeli Acute Paralysis Virus is prevalent in the Middle East, Australia and the USA but less frequency found in Europe (Robin *et al*., 2010). Because of this IAPV has been found to be associated with colony losses in USA (Cox-Foster *et al.*, 2007) but so far not in Europe (Genersch, 2010). The DWV should be considered as a major virus causing the loss of honey bees' colonies. So far there has not been report of presence of honey bee virus in Ethiopia.

2.3. Taxonomy

The taxonomic position of the arachnid varroa is categorized under kingdom *Animalia*, phylum *Arthropoda*, class *Arachnida*, order *Mestigmata*, the family *Varroidae*, genus Varroa, and species *Varroa destructor* and *Varroa jacobsoni* (IBRA, 2013).

2.4. Morphology

The ecto parasite mite varroa is visible to naked eye and its body is divided in to two well defined parts, the idiosoma and the gnathosoma. The whole body, including of legs and mouth parts, is covered with hairs. The adult female mite is brown to reddish- brown in colour, measuring 1.1 to 1.2 mm in length and 1.5 to 1.6 mm in width (about the size of a pinhead) Coffey and Mary, 2007). Its dorsal shell covers an entire idiosoma and the mite has indistinct head and four pairs of short and segmented legs, which protrude from one side of this ellipsoid shell (Coffey and Mary, 2007). Its body fits into the abdominal folds of the adult bee and is held thereby the shape and arrangement of ventral setae (Sanford *et al*., 1998). The flattened shape of the female's body makes it easy for the mite to hold onto the bees and move easily into the cells of developing bee brood.

The adults' male mites are yellowish colour; lightly tanned legs and spherical body shape with smaller, measuring about 0.75 to 0.98 mm long and 0.7 to 0.88mm wide(Huang, 2012). Adult male mites do not feed and are not found outside of brood cells. The adult male chelicerae are modified for transferring sperm. The legs of the male mites are longer in relation to the body size than the legs of females (Huang, 2012).

Figure 1: Dorsal view of adult varroa mite, *Varroa destructor* and the composition of a ''Varroa family" within the honey bee worker brood cell,
(Source: Anderson and Trueman, 2000).

2.5. Eggs

The eggs are oval in shape and white in colour the approximately 0.30mm long and 0.20mm wide, and laid singly on a cell wall (Ellis and Nalen, 2010).In generally; eggs cannot be seen by the unaided eye. Nymphs: Male mite and female mite protonymph are undistinguishable without dissection. Protonymph have 8 legs, pointed chelicerae (mouth parts), and circular body shape and are a transparent white colour. After protonymph. Its, the mite becomes a deutonymoph which resembles the adults with a reduction in setae. Mite will once again moult in to the final adult stages (Ellis and Nalen, 2010)

2.6. Geographical Distribution

The geographical distribution of Varroa mites vary within the type of species. The *Varroa jacobsoni* has the wide distribution throughout Asia whereas *Varroa destructor* is thought to be native to the Far East where it parasitizes the Asiatic honey bee *Apis cerana* and is not invasive, though it has been introduced widely and is now prevalent worldwide, with the exception of New Zealand, Australia and some countries in Central Africa (Sanford *et al*., 2007). Varroa mite infestation is the influenced by seasonal and climate. It is proposed that *varroosis* in cold climate is higher than that of warm climate and its rate of incidence is greater in the cold seasons (fall and winter) than hot and warm seasons of (spring and summer) (Lofti and Shahryar, 2011). There are, obviously, significant differences between the population dynamics in temperate and subtropical/tropical climates with a clearly tendency for lower varroa mite population growth under tropical conditions (Rosenkranz *et al*., 2006).

Under temperate conditions, damage at the colonies level mainly appears during fall and winter, when the host population declines, the relative parasitization increases and consequently the long-living winter bees are damaged.

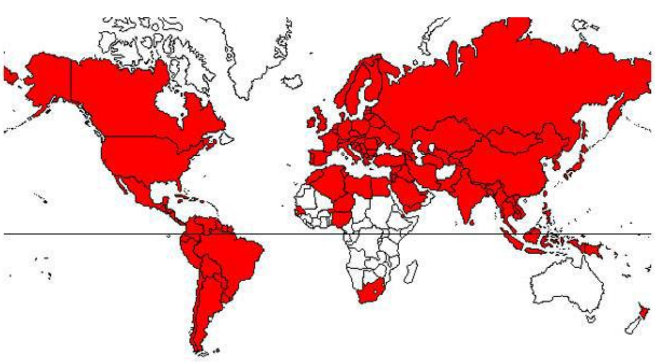

Figure 2: The world varroa mite distribution of -2010, Red areas indicate establishment of *Varroa destructor*

2.7. Transmission

The varroa mites are spread from bee to bee when bees walk past one another in the colony (Ellis and Nalen, 2010). Naturally spread between colonies is through the movement of adult bees carrying mites from one colony to another. In apiaries, these could be due to natural drifting. Movement between apiaries will occur if there is any robbing. Probably, drones will play a big part in the spreading of mites as they are known to move freely between apiaries many miles apart. The varroa mites can also be transmitted between colonies as bees from the colonies rob (steal honey) from one another and beekeepers transferring queens, combining colonies, swapping frames of brood between colonies, and transporting inadequately screened hives and boxes of honey (Goodwin and Eaton, 2001). Varroa mites can be introduced to non-infested regions on natural swarms and when beekeepers move infested colonies. The spread of Varroa mite around the world has been greatly assisted by human being moving honey bees from place to place (Eaton, 2001.

2.8. Life Cycle

Varroa destructor is closely linked to its honey bees host and lacks of a free living stage. There are two distinct phases in the life cycle of Varroa mite's females: A phoretic phase on adult bees and a reproductive phase within the sealed drone and worker brood cells (Sanford *et al*., 1998; Rosenkranz *et al*., 2010). During the phoretic phase, female mites feed on adult bees and they are passed from bees to bees when bees walk past one another in the colonies. Males and nymphal stages of the mites are short lived and can only be found within the sealed brood cells (Harris *et al*., 2003). The life cycle of begins after the capping of the brood cell (Lewbart, 2012). When female mites are ready to lay eggs, they move into brood cells containing young larvae just before the cells are capped and they go to the bottom of the brood cells and immerse themselves into the remaining brood food. After the cells are capped and the larvae have finished spinning cocoons, the mites are start feeding on the larvae (MAAREC, 2004).

Then mite is most attracted by drone brood. Shortly times thereafter, they begin laying eggs approximately three days after the cell has been capped. Subsequent fertilized eggs are laid by the female mites approximately to every 25 to 30 hours and these hatches into female mites (Ellis and Nalen, 2010). The period from egg to adult takes about 6 to 7 days for the female mites and 5 to 6 days for the male mites. Mating occurs in the brood cell before the new adult females' emergence (Nalen, 2010).

The adult male mites die after copulation since their mouth parts (chelicerae) are modified for sperm transfer rather than feeding (MAAREC, 2004). The mature female stored the sperm in the spermtheca and will not mate again (Huang, 2012). The old female mite and the newly-fertilized female offspring remain in the brood cell until the young bee emerges and then exiting the brood cell with the newly emerged bees to complete their reproduction cycle again. Female mites produced in the summer season live 2 to 3 months, and those produced in the fall live 5 to 8 months. Without bees and broods, the mites can survive no more than 5 days (Huang, 2012). The mite's populations increase rapidly during the heavy brood rearing season.

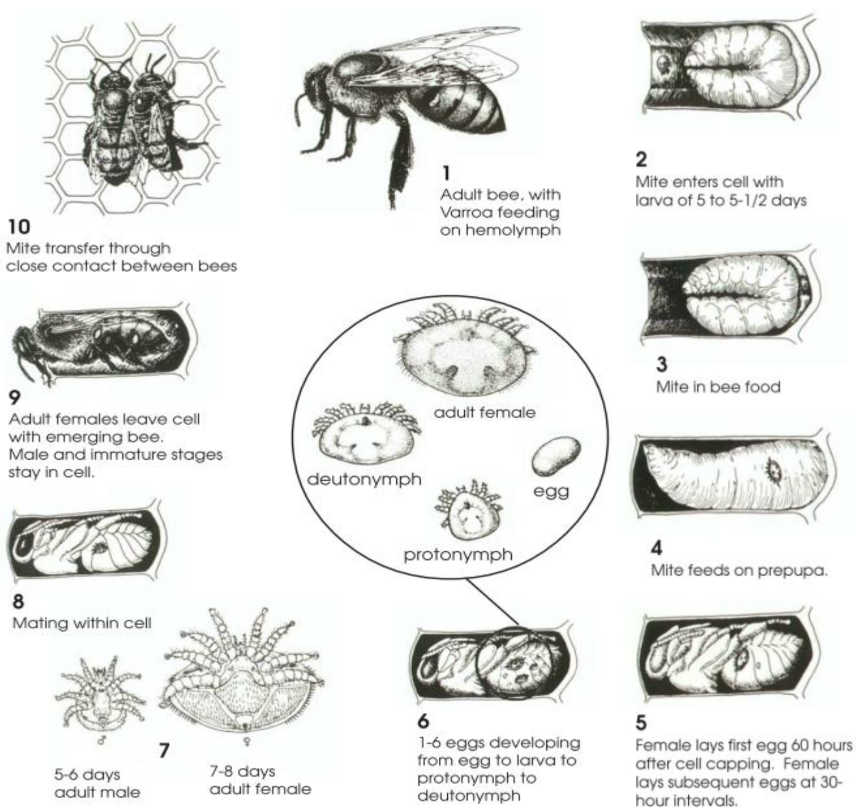

Figure 3: The life cycles varroa mite

2.9. Epidemiology

2.9.1. Host

Varroa mites affect honey bees colonies and among the honey bees that serve as hosts of Varroa mites are *Apis cerana* and *Apis mellifera*. *Varroa jacobsoni* parasitizes only the honey bee *Apis cerana* and it completely lacks the ability to reproducing on *Apis mellifera* (Rosenkranz *et al*., 2010) but *Varroa destructor* affects both *Apis mellifera* and *Apis cerana*. Apis species show that some variation in susceptibility to *Varroa destructor* that usually causes the collapse of *Apis mellifera* colonies in contrast to *Apis cerana* which can support population of mites without collapse. *Apis mellifera scutellata* also an appears to have some resistance or the tolerance to the *Varroa destructor* (Sanford *et al*., 2007).Varroa mite affects both the adult and immature honey bees, but the developing larvae's and pupae's are the most sensitive host stage (Rosenkranz *et al*., 2006).

Figure 4: Mature and immature females and mature males of Varroa mites. Clockwise from top left: mature daughter mite, mother mite, two mature males and the immature (deutonymoph) daughter (Ellis and Nalen, 2010)

2.10. Effects and Clinical Manifestations

2.10.1. Pathological effects

The damage on honey bees is principally caused by the female mites whereas the male mites cause a little damage since they live only short time in the sealed brood cells of bee's colonies (Bruyn, 1997).

Figure 5: Varroa mites are feeding on honey bee's pupa (a) and on the adult honey bee Lew brat (2012)

2.10.2. Effects on the individual honey bees

Initial time Varroa mite infestation is unnoticeable since damage occurs after mite population is built up and this build-up may be over several years or a couple of seasons. The individual honey bee is damaged in a variety of ways, with the developing larvae and pupae clearly representing of the most sensitive host stages. First, the loss of haemolymph during to genetic developments within the brood cell significantly decreases the weight of the hatching bees. The weight loss depends on the number of mother mites and the amount of mite's reproduction, but even a single infestation results in an average loss of body weight of 7% for the hatching bee Rosenkranz *et al*. (2010). The effect of Varroa mites on honey bees come about either directly from the mites feeding on the haemolymph of honey bee adults, larvae and pupae or indirectly as the result of introduction of virus (Goodwin and Eaton, 2001). This has also been providing for parasitized drones, which lose 11–19% of their body weight depending of infestation rate which led to decreased flight of performance (Duay *et al*., 2002).

Varroa mites have piercing and sucking of mouth parts and feed on haemolymph of honey bee adults, larvae and pupae. Individual developing bees, if the infested with one to two adult mites and offspring, usually emerge without visible damage and are normally appearance. They may, however, suffer from malnutrition, brood loss, or disease on honey bees. Individual bees those are heavily-infested with more than a few adult mites (which produce as many as 20 nymphs) usually become visibly crippled or die in their cells without emerging. When the adult bees are infested by two or more mites, they become restless and fly with difficulty. However, individual developing bees that are heavily-infested by more than two adult mites usually die in their cell without emerging or emerge with misshapen wings, deformed legs, shortened abdomen (Hood, 2000). Their life span is generally shorter than unparasitized (normally) bees and they perform tasks poorly. In the drones, spermatogenesis and flight capacity are also affected (Lew brat, 2012).

In addition to the obvious effects of mites feeding on developing and adult bees, the mites can also serves as vectors of several viruses that can kill honey bees. The secondary infections are facilitated when the mites compromise the bees' immune system and they can cause of condition known as parasitic mite syndrome which can kill colonies within months of infection (Tarpy and summers, 2007).

Figure 6: Common symptoms of heavy Varroa infestation a worker bee with deformed wings
Sources (NBU, 2017)

2.10.3. Effect on the colonies

The colonies level, the symptoms of a varroa mite infestation depend upon the degree of infestation (FERG, 2005). At low down infestation rates clinical symptoms are not visible, and the infestation often remains undetected. The moderate infestation rates may reduce the growth of the honey bee population and, therefore, the honey yield, but clinical symptoms may still not be evident. However, the steps to irreversible colonies damage are small, especially if during fall the mite's population still increases while the host population is decreasing (Fries *et a*l., 2003). Drones which have been parasitized during their development times have a significantly lower chance to mate and infested colonies produce less swarm (Fries *et al*., 2003). The final break-down of the honey bee colonies are associated with the typical parasitic mites' syndrome such as scattered brood, crawling or even crippled bees, supersedure of queens and unexplainable reduction of the bees' population.

The affected of colonies activity and production are reduced. The last stage of the disease is the collapse of the colonies (Lewbart, 2012). High mite infestation leads to collapse of the honey bee colonies (Lewbart, 2012). Varroa mite has been identified as the cause of significant losses of both managed and feral colonies in a number of areas of the world. However, feral bees colonies are the most likely to succumb since they are not managed by humans and treated to control mite (Goodwin and Eaton, 2001).

2.11. Diagnosis

Effective of varroa mite control is depends on frequent and reliable mite detection. In the heavily infested area, individual colony infestations can grow from being undetectable to life-threatening levels within a few months. It is important to monitor of varroa mite levels by sampling all or most colonies on a regular basis (Tarpy and summers, 2007). When sampling tack for Varroa mite, remember that the number and location of mites in a colony vary according to time of the year. The number of mites is lowest in spring, increasing during the summer season, and is highest in the fall. During spring and summer, most Varroa mites are found on the brood. In late fall and winter, most of the time mites are attached to adult worker honey bees (Hood, 2000). There are different types of Varroa mite examination methods: Debris examination, brood and adult honey bee examination and laboratory diagnosis (OIE, 2008).

Figure 7: Varroa mites in the different stages of development on a pupal worker and drone bee

Sources (NBU, 2017**)**

2.11.1. Debris examination

Debris is the analysis of the debris collected from the bottom of a hive and examined for the presence of the fallen Varroa mites. It is carried out with the use of a sticky sheet on the hive bottom for retaining the mites fallen from the body of bees. This method is sparing for bees because it does not require disruption of the colonies while detection of mite infestation (Parkman *et al*., 2002). However, the method can be considered reliable only if there is an adequate amount of brood and on the early stages of bees' infestation (Branco *et al*., 2006).

2.11.2. Brood examination

Varroa mites spend most of their life cycle inside sealed bee's brood cells; therefore, uncapping and checking brood (pupae) for mites are the reliable detection method. Look at mites on brood, the pupae (preferably drone) are examined and mites can be easily seen against the white surface of worker or drone pupae after they are removed from their cells. It is suggested that the minimum of 100 pupae per colony be examined. The result from the diagnosed brood showed that all of the sampling localities were 100% infested with varroa mites with the infestation rate ranging from 33% to 100 %(Desalegn Begna, 2014). The pupae can be removed from their cells by inserting a capping scratcher at an angle through the capping and lifting of the brood and capping upward (Hood, 2000). Examination of preimaginal bee stages (larvae and pupae of workers and drones) in newly capped brood combs for the presence of mites can be carried out by looking through a strongly light. However, brood examination is a protracted labour-consuming procedure and can be implemented only during the presence of brood in the hive (Calderon, 2005).

2.11.3. Direct observation of adult honey bees

When the mites are moving about on the honey bees they are fairly easy to detect; but once they attach to themselves between segments, they are difficult to find (Bienefeld and Zautke, 2007).

2.12. Laboratory Diagnosis

Accurately and easy methods of predicting mite levels in colonies can be carried out by using various sampling techniques. The most important laboratory methods are: Alcohol wash method, ether roll and sugar shake method (Tarpy and summers, 2007).

2.12.1. Alcohol wash methods

This method is simply, quickly and quite accurate when applied to a larger number of colonies in the apiary. Ether roll test is simply but less accurate than the alcohol wash methods because it is more difficult to obtain an accurately count of the number of mites in the sample. Sugar shake methods can be used instead of ether roll where all the bees are killed (Fakhimzadeh, 2001).

2.12.2. Differential diagnosis methods

The bee-louse, *Braulacoeca* (a wingless fly that lives harmless on adult bees) may be confused with Varroa. It can be distinguished from Varroa *b*y its more rounded shape and its six legs but varroa mite eight legs which are readily visible on both sides of its body (OIE, 2008). Two other mites that should be distinguished are *Tropilaelapsis* species and *Melittiphisalvearius*. *Tropilaelaps*is a serious exotic pest of the honey bees and is fortifiable *Melittiphis*mites are predatory mites, preying on scavenger mites that occur in bee hives. They do not harmless honey bees or their brood (FERG, 2005).

2.13. Treatments

Nowadays, different chemicals are available for the treatment of Varroa mite infestation, even though some of them are ineffectively and others have and limitation due to their effect on the bees and beekeepers. These chemicals can be organic *varroacides* like to essential oils and organic acids, and synthetic *varroacides* including of *fluvalinate, flumethrin* and *coumaphos* (Goodwin and Eaton, 2001). Varroacides (specific *miticides*) are applied in the feed, directly onto the adult bees, as fumigants, using contact strips or by evaporation (FERA, 2010). The challenges of treatment *varroosis* are that the mites have developed resistance to many of the synthetic varroacides used and the wide spread use of chemical treatments lead to the presence of drug residue in honey, beeswax and other honey bees' products. Re-invasion of mites in to treated of the colonies from untreated colonies is also a major problem in *varroasis* treatment (Murielle and Baggio, 2004).

2.14. Economical Impact of Varroa Mite

The significant of potential impacts Varroa mites include economic, social and environmental concerns in country. These mites have affected of the apiculture industry negatively impact in every country that it has been introduced. Accurately estimates of the effect of Varroa on the apiculture industry is hard to find, but it is safe to assume that the mites have killed hundreds of thousands of colonies worldwide, resulting in billions of dollars of economic loss (Ellis and Nalen, 2010). Apiculture is severely affected by the activities of *Varroa destructor*, either by direct parasitism or indirectly by facilitating the spread of bee's viruses and diseases. If left unchecked, mites can infest hives beyond an economic threshold and lead to colonies collapse within a two years period (FERA, 2010). This is necessitates very careful management from beekeepers perspective to detect and treatment of varroa mites as and when their population increases to critical levels. There is significantly cost in materials and labour involved in Varroa management (Rosenkranz *et al*., 2010). Thus, losses in numbers of Apis mellifera due to infestation by *Varroa destructor* could lead to substantial negatively but indirectly impacts from lower crop yields due a lack of adequate pollinators. Collapse of colonies due to Varroa mite can also have a serious side effect on peoples who rely on beekeeping for their livelihoods. Regular treatment of varroosis can cause chemical residues in honey bee products and production which result a great effect on the consumer.

2.15. Prevention and Controls

Varroa mites cannot be eliminated from honey bee colonies, but beekeepers can be monitor its presence and still maintain productive of honey bees, and control methods can be used to keep mites at a manageable level (FERA, 2010). Prevention and control of this mite can be carried out using the different methods. These methods are including biotechnical, biological, and chemical methods. However, they are only moderately effective when they are used alone, so that an integrated prevention and control approach is best of best.

2.15.1. Biotechnical methods

These methods involve beekeeping management techniques specifically designed to reduce mite levels in the colonies. Biotechnical methods are generally not used as a complete means of Varroa mite control. However, they are often incorporated into the IPM systems, whether with synthetic chemicals, or more generally with organic control substances. Common types of biotechnical methods are used: drone brood removal and trapping, artificial swarm, open mesh floors, and dowdy method (FERA, 2010). Open-screen floors in hives may interfere with mite population growth by decreasing the rate of which mites invade brood cells, yields leading to fewer mites, a lower percentage of mites in brood cells and more cells of capped brood compared with hives with wooden floors. The highest proportion of Varroa mites can be removed from honey bee colonies by creating an artificial swarm.

These involvements of moving the parent colony approximately 4 meters from the original colony site and second hive containing newly drawn combs and the queen is placed on the original sites, causing foragers to return to those hives, creating an artificial swarm (FERA, 2010). Brood removal and trapping for control of Varroa is treatment based on the understanding that mites are confined in honey bee brood cells once the cells are capped. The mites can consumer therefore easily can be removed from the colony without the mites being able to escape back onto the adult honey bees. Probably the most of well-known biotechnical control eliminated method for Varroa is drone brood removal and trapping. Drone brood is generally used for this purpose because varroa mites show eight to ten times greater preference for drone brood than for worker bee brood. Removal of worker brood can be also reduce mite levels, but it greatly affects colonies productivity and is labour intensive (Goodwin and Eaton, 2001).

2.15.2. Chemical methods

This method of mite control involves various methods of application and ways of dispersal of acaricides, which are determined by the nature of the chemicals being used. The varroacides (specific *miticides*) are applied into the feed, directly onto the adult bees, as fumigants, using contact strips or by evaporation (FERA, 2010). Various chemicals have been demonstrated an ability to control Varroa mite in honey bee colonies. These chemicals can be divided into two organic and synthetic. The three most of common synthetic chemicals which are used to control Varroa mites are *fluvalinate (apistan), flumethrin* and *coumphous.* The essential oils and organic acids are the two organic mite control substances (Goodwin and Eaton, 2001).

However, Varroa mites have been a demonstrated ability to become quickly resistant to these chemicals. This has made many acaricides useless in those areas where Varroa resistance to chemicals has been developed. Many of these substances are not easily to apply and they are dangerous both to the colony and humans. The effects of chemical treatments on honey bees including reduce longevity of queen bees, reduced sperm loads in and longevity of drones, brood death, and reduced queen egg laying patterns (Ellis and Nalen, 2010).

2.15.3 Biological methods

This Varroa control methods involving of use the bee's biology, perhaps its natural resistance against mites. The desirable features of honey bees that can be selected to establish a resistant honey bee colony include higher hygienic behaviours and grooming activities, shorter post capping periods, low attractiveness of brood to varroa mites, and low mite fecundity factors. The selection and establishment of resistant bee colonies is the best and cheapest method of control of varroosis since the bees themselves deal with Varroa mites. Achievement of this control method is, however, it's taking longer time and short term solutions, such as biotechnical or chemical methods have to be used in the meantime to stop colony death (Tarpy, and summers, 2007).

Chapter 3.MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

Metema district is one of the districts in West Gondar administrative Zone of Amhara National Regional State. Metema is located between 12º50'0" N and 36º20'0" E, 500-1666 meters above sea level and it is the largest district in the Zone (Figure 8).The district has 24 (22 rural and 2 urban "*Kebeles*") administrative "*Kebeles*" The district is bounded by **Abraha Jira** district in the North, **Chilga** district in the East, **Quara** district in the South and **Sudan** in the West (WoARD, 2019).Metema is located at about 925 km Northwest of Addis Ababa and about 180 km West of Gondar town. Metema is one of the North Western districts of the Amhara Regional State. The district has an international boundary of more than 60 km long distance between Ethiopia and Sudan.

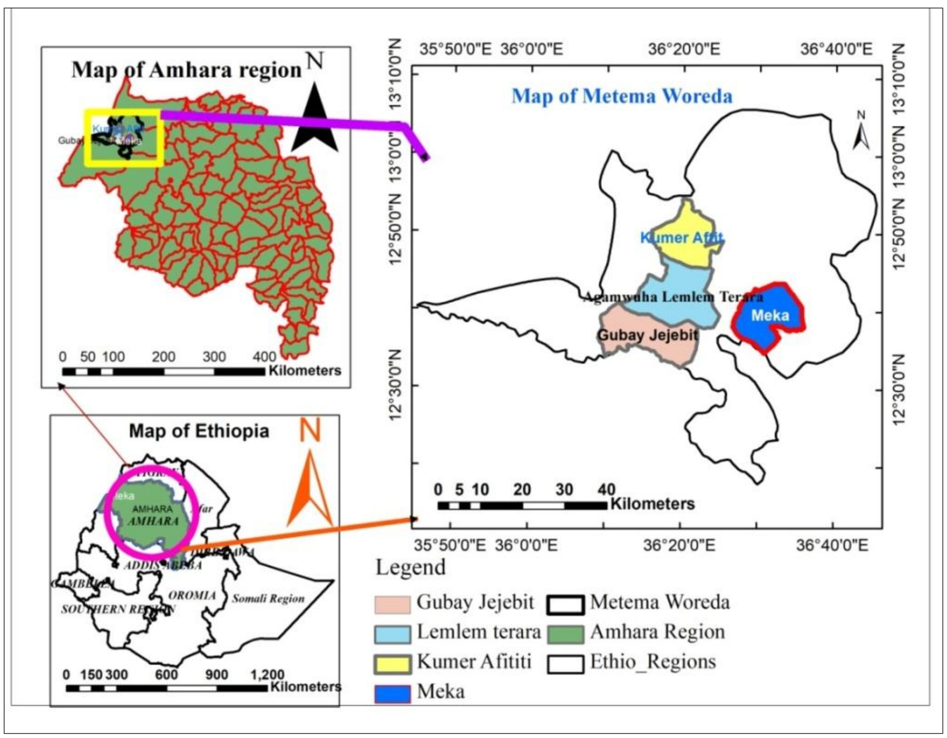

Figure 8: Map of study area

3.1.2. Topography and Areal Coverage

The topography of Metema district is characterized by plain land. This indicates that the larger proportion of the district is characterized by more than 90% less than 1000 meter above sea level. The total areal coverage of the district is about 440,085 hectares (WoARD, 2019).

3.1.3. Climate

According to District Agricultural and Rural Development Office (WoARD,2019) the district has kola (low land) agro-ecological zone .Altitude range 550-1608 masl with annual temperature range 28-43^{0}C. The daily maximum temperature becomes very high during the months of March to May, during which the temperature can reach as high as 43^{0}C. The mean annual temperature is about 31^{0}C (ILRI, 2010). Mean annual rain fall of Metema district area ranges from about 850 to around 1100 mm, and it receives unimodal rainfall (ILRI ,2010). The raining months in the district extend from June to the end of September. However, most of the rainfall is received during the months of July and August, during which the rainfall is erratic.

3.1.4. The land use

According to the District Agriculture and Rural Development Office(WoARD,2019) the land use of the district is classified in to 86,360 hectare for the farmland; 4,400 hectare for the grazing; 177,600 hectare for the forest; 3,660 hectare for the settlement from this 894 hectare is used for the social services; 116.2 hectare for the perennial crops; 89,943 hectare for the bushes and shrubs; 3708 hectare is covered by the water bodies; 17,471 hectare could be the cultivated; 7752.2 hectare is unusable and the remaining 6800 hectare is for the miscellaneous activities(WoARD,2019). Forest and bush land are diminishing over time due to the farm land expansion.This depicts that land use type and pattern of Metema district is more diversified. The nature of land use in the districts is that larger proportion of the land is used for forest land. The land area used for perennial crops (about 0.03 %) is smaller than others followed by irrigable land and settlement area and land covered by water bodies, respectively (WoARD, 2019).

3.2. Human Population and Livestock Resources

According to CSA (2016) the population of Metema districts was about 110,231 (69,002 males and 41,229 females).A total of 88,354 (80.15%) population are rural inhabitants and 21,877(19.85%) are urban dwellers. This indicates that the numbers of rural inhabitants are more numerous than urban dwellers. The inhabitants of the district are belonging to the Amhara ethnicity and Amharic and to some extent Arabic are media of communication. With regard to religion the majority of inhabitants are followers of Orthodox Christians (90 %) and the remaining are Muslims (10%). The population density of the district is about 25 persons per square kilo meters.

3.3. Farming System

The major economic activity in the district in which the population engaged is mixed farming, which is a combination of the crop production and the livestock rearing and to some extent legal and illegal trade because of its proximity to the border. Due to erratic and torrential rainfall pattern the farming operation is always at risk such as crop failure due to drought, shortage of livestock feed *etc*.The agricultural production system in the study area is the crop -livestock mixed. The crop - livestock production system is the predominant system and exists in all over the district throughout the year. The crop production is the main agricultural activity for the livelihood of the smallholder farmers in the study area. The major crops grown include sorghum, rice, cotton, sesame, haricot bean, soybean and new emerging crops like tiff, chickpeas and banana (WoARD, 2019).

Livestock production is an integral part of land use system. Production of the Cattle (as draught power, milk and meat), Shoat (income and meat), Donkey and camel (as Karoo and transport) and Poultry(meat and egg)are commonly practiced. According to Metema district Livestock and Fishery office (MoWLF, 2019) report, the livestock population of the district is composed of 359,993 cattle, 109,536 goats, 60,185 sheep, 20,246 donkeys, 7,127 poultry, 29 camels and 13,176 beehives. Cattles in the district are exported both in legal and illegal system, through smuggling to Sudan, while goats and other animals are mainly sold in the local markets. The major Cattle breed of the study area is Fogera crossbred with other highland

Zebu cattle, Ruthana cattle originally from Sudan, Mahibere Silase cattle from Mahibere Silase Gedam and Felata cattle from Niger and Nigeria also constituted smaller proportion of the cattle population. The main small ruminant resource is goat production. There is a small proportion of sheep population locally known as the 'Gumuz sheep'. Important livestock diseases include infectious diseases, internal and external parasites.

According to ILRI (2010) Metema district was categorized into cotton, sorghum and rice/ livestock based/ and sesame, cotton, and sorghum/ livestock based farming systems based on the type of crop production. The livestock production system is similar in both farming systems. Therefore, there are two types of farming systems used in the study district namely Cotton based farming system and Sesame based farming systems. Each has its own characteristic the features regarding to the crop production nature. According to ILRI (2010)four out of eighteen peasant associations belong to cotton farming system: they are Meka, Awlala, Genda Wuha and Kemechela found in the Northeast parts of the district. The Peasant Associations are relatively colder in temperature, have higher altitude and rainfall. Farmers in the Peasant Associations practice slightly early.

3.3. Sampling Technique and Sample Size

Diagnostic survey and collections of adult bees and brood samples (both drone and/or worker brood) was conducted from October 2019 to March 2020 in 4 "*Kebeles"* (Meka, Lemlem Terara, Kumere Aftiti and Gubay Jejebet) among 22 "*Kebeles*" of Metema district. The "*Kebeles* "were randomly selected based on honey production and abundance of honey bee colonies (Table 1).

Table 1: List of rural and urban Kebeles and types hive in Metema district (2019-2020)

No	List of rural Kebeles	Types of hives			Total
		Traditional	Transitional	Modern	
1	Meka	564	40	61	665
2	Kumer Awolala	589	0	0	589
3	Kemechela	649	0	0	649
4	Achera	832	0	0	832

5	Zebachibahire	725	23	7	755
6	Kumer Aftiti	385	44	64	493
7	Gendewa Birshigni	690	0	0	690
8	Wode Gemzo	652	0	0	652
9	Dasi Gundo	298	43	36	377
10	Metema Yohanise	578	2	23	603
11	Mender 6,7,8	289	0	0	289
12	Agab Woha	780	31	23	834
13	Lemlem Terara	470	55	85	610
14	Shimelegara	356	5	0	361
15	Tumet Mendoka	568	0	0	568
16	Lincha	346	0	0	346
17	Shashige	516	0	0	516
18	Gobay Jeibet	465	43	74	582
19	Mesheha	432	0	0	432
20	Lasta	567	0	0	567
21	Delelo	543	0	21	564
22	Ashamet	1202	0	0	1202
Total		12496	286	394	13176
No	List of Urban Kebeles				
1	Kokite	652	0	0	652
2	Shinfa	356	3	0	359
Total		1008	3	0	1011

Sources: MoWLF, 2019

There are a total of 825 beekeepers in the selected kebeles then the sample size in 4 kebeles was 107 according to Yamane (1967) formula. $\boldsymbol{n} = \frac{\mathbf{N}}{\mathbf{1}+N(e^2)} = \frac{\mathbf{825}}{\mathbf{1+825(0.09^2)}}$ =107.Where: **n**= sample size, N= total population and **e**= is the level of precision (e=0.09).

From the selected "*Kebeles* "the respondents were selected randomly who engaged in bee production, long beekeeping practice. A total of 825 beekeepers were participating in beekeeping in4 selected "*Kebeles*" (A total of 250 beekeepers in Meka: 32 beekeepers were sampled, a total of 230 beekeepers in Lemlem Terara: 29 beekeepers were sampled, a total of 195 beekeepers in Kumer Aftiti: 25 beekeepers were sampled and a total of 150 beekeepers in Gubay Jejebet: 21 beekeepers were sampled) of this beekeepers 107 beekeepers were randomly selected for interview. Samples were collected from local bee colonies hive in Zander (frame), Transitional and Traditional hives (total hive from selected 4 kebeles frame hive 284(Meka =61, Lemlem Terara =85Kumer Aftiti =64and Gubay Jejibet =74), Transitional hive 182(Meka =40, Lemlem Terara =55, Kumer Aftiti =44and =43) and Tradition hive 1884(Meka =564, Lemlem Terara =470Kumer Aftiti=385 and Gubay Jejibet=465) respectively (Table 2).

From each "*Kebele''* 24 honey bee colonies were inspected from 2 apiary sites (8 bee colonies from each hive type and 2 apiary sites from each Kebele) 8 apiaries sites and 96 honey bee colonies were and brood bees randomly (Table2).

Table 2: Total hives and sampled hives and also total apiaries site and sampled apiaries site in selected Kebeles in Metema district

Kebeles	Total Types of hives in each selected Kebeles			Total	Total apiaries site in each Kebeles	Sampled hive in each selected Kebeles			Total	Sampled apiaries site in each Kebeles
	Traditional	Transitional	Modern			Traditional	Transitional	Modern		
Meka	564	40	61	665	3	8	8	8	24	2
Lemlem Terara	470	55	85	610	4	8	8	8	24	2
Kumer Aftiti	385	44	64	493	4	8	8	8	24	2
Gubay Jejibet	465	43	74	582	4	8	8	8	24	2
Total	1884	182	284	2350	15	32	32	32	96	8

3.4. Collection of varroa mite on the adult honey bees methods

Collected samples were examined for the presence of varroa mite and it's the level of infestation using the standard methods for varroa mite research described in Dietemann *et al.* (2013).During this study, from each bee colony 300 adult honey bees were shaken off or brushed off from their brood combs in a colony directly into a wide mouth plastic container and solution was added immediately killed using hot water and placed in 10 ml of 1% detergent-water solution (10 ml detergent in 1000 ml water) and vigorously shacked for 1 minute to dislodge mites. The mites were collected filtering the solution through a ladle (8- to 12-mm-mesh) that hold the bees and let out the mites with the solutions. Then wire gauze (less than 8 mm mesh) was used to hold the mites and discharge the solutions (Appendix Figure 5). The varroa mites were then collected by pouring the bees in a detergent solution into the double sieve and the mites were transferred to an absorbent paper immediately after washing them off to help them dry up.

The magnifying hand lens was used to examine the presence/absence of the mite was examined. Subsequently counting was done on diagnosed adult bees and recovered varroa mites of mites on the absorbent whitish paper (Dietemann *et al* 2013).Finally, the numbers of collected mites per sample and the total number of the sampled honey bees were counted. In order to determine the proportion of infested individuals, the total counted number of mites was divided by the number of bees in the sample and then was multiplied by 100 to obtain number of mites per 100 bees (Dietemann *et al* 2013). For the component of monitoring of this study, to dislodge the mite from the bees for analyzing varroa population dynamics throughout the whole season, the lower numbers of Individuals 100 bees per sampling date per colonies.

3.5. Collection of brood for varroa mite methods

From a brood containing frame, 100 randomly selected capped cells (*i.e.* a pupae comb which is 5cm x 5cm) were cut, rubbed with a plastic bag and transported to the laboratory for further analysis (Appendix Figure 10). Each of the cells in 5 cm by 5cm of brood comb were then opened, larvae or pupa were pulled out using soft forceps and examined for the presence/absent of mites and its infestation level (Appendix Figure 11). The mite of infestation was diagnosed by observing the mites themselves or from their dejection or symptoms (white rubbery material, most of the time located on the two upper walls, towards the bottom of the cell).

The examinations for varroa mite on the surfaces of the pupae was aided by a magnifying hand lens and number of varroa per diagnosed sample was then recorded. In order to the determination the proportion of mite infested cells, the total number of cells opened and infested cells were counted. And then the numbers of infested cells were divided by the total number of opened cells and multiply by 100 to obtain the proportion of the mite infested cells.

3.6. Method of Data Collection

Data was collected by interviewing the beekeepers and formal (diagnostic) survey by using semi-structured questionnaire, group discussion and key informant interview techniques of survey data collection were also applied to further understand practical problem of beekeeping as to whether varroa mites are threat to honey bees in the district. Data on bee hive production and challenges for beekeeping farming in the area, status of individuals and cooperative involved in beehive farming, interest of the community and cooperatives toward bee keeping practice in the area were incidence rate and Varroa mite infestation rate was assessed. In addition, secondary information from office of agriculture and other organizations relevant for this study was collected. Enumerators, who can speak local language with a minimum of grade10 educational backgrounds of total of 12 individuals were employed and trained for at least three days on the objectives of the study, ethical issues, method and approach how to administer formal survey questionnaire and data collection to Varroa mite.

3.7. Data Analysis

Data collected was managed in such a way that the qualitative as well as quantitative variables are selected. The data collected by using semi-structured questionnaire was entered in to MS-excel and imported to SPSS (version 23.0) software and also coded for analysis. Descriptive statistics was used to describe quantitative factors. Standard deviation of mean ± (SE) was used to describe means while percentage was used for describing qualitative characteristics. The results were expressed in percentage and mean ± SD at p-value <0.05significance level of the results from the questionnaire and infestation rate analysis. The quantitative data is subjected to one way Analysis of Variance (ANOVA) procedure of the SPSS (version 23.0) software.

Finally, mite occurrence, infestation rate, favourable seasons, economical impacts, hive type and effect of colony strength was determined.

Logistic regression of incidence rate

$Y_{x1x2x3} = B_0 + B_1 x_1 + B_2 x_2 + B_3 x_3 + E_{x1x2x3x4}$

$Y_{x1x2x4=}$ Incidence rate (brood and adult bee)

B1x1 =Colonies lose (brood and adult bees died of mite)

B2x2=Hive type (Traditional, Transitional and Modern)

$B_3 x_{3=}$Season (Active, Dearth)

$E_{x1x2x3=}$Residual error

- The logistic bi Model that was used for Data Analysis:

$Y_{ijk} = \mu + A_i + B_j + S_{kI} + E_{ijkI}$

Where: Y_{ijk}= Measuring of different parameters (infestation rate on brood and adult bees)

A_i = Colonies lose (brood and adult bees died of mite)

B_j = Hive type (Traditional, Transitional and Modern)

S_K = Season (Active, Dearth)

E_{ijk} = Residual error

Chapter 4: RESULTS AND DISCUSSION

4.1. Socio- Economic Characteristics of Households

4.1.1. Households' charactestics

According to the results of the study, majority 90.7%, of sampled respondents interviewed to generate qualitative and quantitative data in beekeeping were males and the rest 9.3% were females (Table 3). This result is in line with Alemu Tsegaye *et al*. (2015), Taye Beyene and Markus Verschuur (2014) and Malede Birhan *et al.* (2015) who reported the majority of respondents in South Wollo and Waghimra Zone (91.1%), Wonchi District South West Shewa Zone of Oromiya Region (94.4%) and around Gondar (87.5%) were males respectively. This result indicated that majority of the beekeepers in the study area were males, although beekeeping is an activity which can be done regardless of sex differences. The participation of very limited the number of females in the beekeeping found in the study area was in agreement with Abebe Jenberie (2008) and Abebe Mitkie (2017).

This might be due to the fact that although the females have significant involvement in all or parts of beekeeping, it has been reported that the beekeeping is duties and responsibilities of men which underscores beekeeping to be men's job due to physical reasons it requires. The age group between 20 and 60 years are generally considered to be economically active age group in many findings (Alemu Tsegaye *et al.,* 2015). The result of this study confirmed that the majority (88.8%) of the households interviewed were categorized in this age group (Table 3).The age characteristics indicated that most of the respondents fell within the range of 31-60 years (45.8%) followed by 43.0% (18-30 years) and only (11.2%) of the sampled respondents were aged above 60 years (Table 3).This study result is in agreement with Sisay Fikru *et al.* (2015)who reported that the most of the respondents fell within the range of 46-65 years (57.10%) followed by 28.6% (16-45 years) and only (14.3%) of the sampled respondents was aged above 65 years respectively in Jigjiga Zone, Somali Regional State, of Ethiopia.

The total households interviewed, 90.7% of the respondents were married while single (3.7%), widow(1.9%), divorced (2.8%) and widower (0.9%) respectively (Table 3).Based on the results of this study, the people regardless of their marital status, they have been observed to undertake beekeeping activities in the study area.

This result is agreement with Abebe Mitkie (2017)and Tessega Bellie (2009) who reported majority of the beekeepers (95.8% and 97.5%) were married in Tehuledere District and Burie districts Respectively. Coming to religion of interviewed participants, 72.0% were Orthodox while the rest 28.0%) were Muslims (Table 3).Regarding family size, respondents had an average of 1.95±0.692 persons per beekeeper which is slightly similarly the national average of six persons per household) ranging from 1 to 3 people per family. Furthermore, the majority of the respondents (73.8%) had a family Size of greater than five and (26.2%) lowers than five (Table 3).This, in turn, has revealed that households with the large family size (both females and males) were most of benefited to perform the different agricultural activities including most common beekeeping activities such as beehives inspection, settling Swarms, water and feed provisions, assisting the household during honey harvesting and so forth (Adebabay Kebede *et al*.,2008).

Table 3: Household characteristics of the respondents in Metema district (n=107) in 2019-2020

Parameter	Variables	Frequency	Respondents (%)
Sex of the household head	Male	97	90.7
	Female	10	9.3
Age of the household head (years)	18-30 years	46	43.0
	31-60 years	49	45.8
	>60 years	12	11.4
Marital status of respondents	Single	4	3.7
	Married	97	90.7
	Divorced	3	2.8
	Widow	2	1.9
	Widower	1	0.9
Family size of respondents	1-5 family numbers	28	26.2
	6-10 family numbers	56	52.3
	>10 family members	23	21.5
The level of education	Illiterate	18	16.8
	can read & write	28	26.2
	primary education(1-4)	29	27.1
	junior(5-8)	17	15.9

	secondary education(9-12)	15	14.0
	<0.5 hectare	39	36.4
The land of holding(ha)	0.5-1 hectare	45	42.1
	1.1-2 hectare	18	16.8
	>2 hectare	5	4.7
The religion	Orthodox	77	72
	Muslim	30	28

4.1.2. Educational Status of Respondents

Regarding to level of the education 27.1% of respondents attended their primary education, 26.2%can read and write, and 16.8% illiterate (Table 3). This result is in agreement with Abebe Mitkie (2017) who reported that 26.4%, 37.2%, and 10% of the respondents have attended the basic education, Grade 1-4, and Grade 5-8 in Tehuledere district South Wollo Zone, Amhara Regional State, Ethiopia respectively .From the total respondents 51.9% were literate and the remaining was illiterate in Amhara Regional State, Ethiopia (Sisay Yehuala *et al*., 2013). The result of this study indicated beekeeping is being practiced by literate beekeepers who can understand the majority of training packages and different advises which has been described by their colony management skills and productivity of their colonies.

4.1.3. The land holding of respondents

The average land holding of the sample respondents during the study period was 1.90±0.846 hectares. This is slightly higher than National average which is 1.0 - 1.5 hectares of land. It is also greater than regional average (1.45 hectares), 1.25 hectares of Enable and 1.77 hectares of the Bure districts reported by Adebabay Kebede (2008), Kerealem Ejigu (2005) and Tessega Bellie (2009). About 5.2% of the sample respondents have no private land holdings. This result supports the fact that beekeeping can be exercised practiced by the landless people and where land is a very limiting factor.The majority (78.5%) of the beekeepers had less than one hectare of land and very few (4.7%) of them had owned more than 2 hectares of land (Table 3). This result also in line with Alemu Tsegaye *et al.* (2015) who reported that (69.8%) of the beekeepers had less than one hectare of land and very few (2.4%) of them had owned more than 2 hectares of land in South Wollo and Waghimra Zone .Amhara Region State, Ethiopia. This indicated that households with limited plot of land may invest more on beekeeping activity since the sector is demanding relatively less land-resource.

4.2. Beekeeping Practice of the Respondents

4.2.1. Reason for involvement in beekeeping

Beekeeping is an important agricultural activity and the major component of livelihood in this study area. As far as the driving forces to engage in the beekeeping business is concerned, about 46.8% of the respondents have noted that they assume the beekeeping agribusiness had a useful role both as a source of income and home consumption for the household immediate expenses and for the home consumption (35.5%) and very small number of respondents (18.7%) income source were noted that they have started beekeeping practice, respectively (Table 4).All of the sampled respondents have agreed on the point that use of honey at home served as beverage(29.0%), as medicine (26.2%), as a source of food(24.3%),and for cultural, ritual ceremony (20.6%) of the respondents have noted the honey they produce has contributed household members respectively(Table 4).

4.3. Beekeeping Experience of Respondents

From the result obtained, about 24.3% of beekeepers have 10-15years and 41.1% of them have above 15 years of beekeeping experience (Table 4). This result was in line with the findings of Alemu Tsegaye *et al*. (2015) and Assemu Tesfa *et al.* (2013) who reported that the average experience of the beekeepers in South Wollo and Waghimra Zone (39.3%) and Western Amhara (41.1%) of respondents have more than 15 years of experience in beekeeping.

Table 4: Beekeepers experience, source of starter colonies, driving force to start beekeeping (n=107) in 2019-2020

Parameter	Variable	Frequency	Percent (%)
Experience in beekeeping(years)	>15years	44	41.1
	10-15years	26	24.3
	5-9years	21	19.6
	1-4years	16	15.0
The source of colonies	Gift from parent	15	14.0
	Catching swarms	53	51.4
	Buying	17	15.9
	gift from parents and catching swarms	20	18.7
Driving force to engage in the beekeeping	Income	20	18.7
	home consumption	38	35.5
	income and home consumption	49	46.8
The home use of honey	As food	26	24.3
	as medicine	28	26.2
	as beverage	31	29.0
	cultural ceremony	22	20.6

4.4. Source of Starter Colony and Placement of the Hive

In order to be engaged in beekeeping business, majority of the respondents (51.4%) have revealed that they have obtained their starting colonies from a swarm catching (Table 4).From this result, it can be concluded that catching swarm is the main sources of the honey bee colonies in the study area. The result of this study is in line with the findings of Marta Zelalem (2013) and Wely Kiros and Tekleberhan Tsegaye (2017) who reported that (53.2%and 71%) started beekeeping by catching bee swarms of the beekeepers in Jimma, Illubabor Zone of Oromiya Regional State, Ethiopia and Selected districts of Gedeo Zone, Southern Nation, Nationalities and Peoples Regional, State, Ethiopia respectively have got their establishing the colonies by catching swarms. Most of the beekeepers in the study area kept traditional, transitional and modern beehives at their eave of the house to prevent from rain and extreme sunbeam.

The higher percentage of the respondents put their bee hives in closure areas (Table 5). However, there are youths of common interest groups that place their modern and transitional beehive the colonies in the rehabilitated closure areas. According to the beekeepers, the main reasons for beehive placement (apiary) selection are close supervision, controlling from theft, and the availability of bee flora. Similar observations were reported by different researchers in different areas of the country (Yetemwerk Gebire-Meskel, 2015). Regarding to the beehive placement Deborah and Devid (2008) sited by Yetemwerk Gebire- Meskel, (2015) that recommended to the groups of 4-8 beehives should be placed at a distance of 0.1524 km in order to allow the bees to take advantage of the early morning bloom(flowering) time. An apiary can accommodate up to 20 bee hives depending on the availability of the flowering trees and bee forages up to 3 km from the apiary (Kangave Alice *et al.*, 2012). It is also important the direction of the hive entrance along the sunlight to encourage the bees for early foraging.

Table 5: Placement of the different hive types of the respondent in Metema district (n=107) in 2019-2020

Site (placement) of the hive	Traditional hive (%)	Transitional hive (%)	Modern hive (%)
Hang on tree	13.35% (697)	18.47 (70)	12.55% (65)
In side house	20.57 %(1074)	26.12 (99)	20.66% (107)
Backyard	32.08%(1675)	21.11 (80)	30.89% (160)
Closure area	34.00% (1775)	34.30 (130)	35.91 (186)

Note: values in the parenthesis ( ) represent number of hives

4.5. Honey Bee Colony Holdings

Based on the levels of technology and management practices used by the beekeepers three beekeeping production methods were identified in the study area: traditional, transitional and modern the honey bee production systems. Accordingly, the majority of the honey bee colonies of the area (86.31%) were kept in traditional hives (Table 6). This result is lower than the findings of Adebabay Kebede *et al*. (2008) but greater than Alemu Tsegaye *et al*. (2015) who reported 99.7% of the respondent beekeepers in Amhara region and 74.02% in South Wollo, Waghimra Zone kept honey bee colonies in traditional hives respectively. This in turn approved that the number of the honey bee colonies in traditional hives is still higher compared to the modern and transitional hives in the study area. Of course the number of the traditional hives is decreasing from year to year as the beekeepers are transferring their colonies to improved hives. Moreover, the distribution and ownership of transitional hives by the interviewed respondents have been observed to be lower than the modern hives.

More specifically, about 8.07% of the honey bee colonies were hive in modern hives (Zander hives) (Table 6). Low adoption and dissemination of movable frame hive attributed to many factors like weak extension, initial high costs, for demanding its own seasonal management techniques and other accessory equipments, poor economic back ground of the beekeepers, lack of knowhow and the likes (Adebabay Kebede *et al*.,2008).

Table 6: The number of honey bee colonies of the respondents within three years in Metema district (2016-2018) n=107 in 2019-2020

Hive types	Number of colonies			Total (mean)	Percent (%)
	2016	2017	2018		
Modern	210	178	125	171	8.07
Transitional	126	117	114	119	5.62
Traditional	1903	1813	1768	1828	86.31
Total	2239	2108	2007	2118	100

Based on this study, 46,7% and 42.1% of the respondents have agreed on a point that there is a decreasing trend in the number of honey bee colonies and their honey yield (Table 7) from time to time due to the availability and occurrence of various threatening factors which had an adverse effect on honey bee health and their production potentials. More specifically, 15.0%, 13.1% , 11.2% and 10.3% of the sampled respondents have identified that presence of absconding, drought and migration and also pest, predator and parasite were the main reasons (threatening factors) for the colonies decreasing trends observed, respectively (Table7). This result agrees with the results of Adebabay Kebede et *al.* (2008), Tessega Bellie (2009) and Tewodros Alemu (2013) who reported(14.3%,16.2% and 13.6%) the decreasing trend of honey bee populations and their products in Amhara Region, Bure and Sekota districts, respectively. Due to multitude reasons like shortage of bee forage, draught, pesticide and herbicide application, lack of water, the poor management and decreases.

Table 7: Trends in the number of colonies, colonies yield, the possible reasons for a decreasing trend in Metema district (n=107) in 2019-2020

Parameter	Variables	Frequency	Response (%)
Trends in the number of colonies you owned	Increase	27	25.2
	Decrease	50	46.7
	No change	30	28.1
Trends of colonies yield you owned	Increase	22	20.6
	Decrease	45	42.1
	No change	40	37.3

Table 8: Index rank of reason for decreasing bee colonies in Metema district (2019-2020)

Problems	Relative degree of importance													Index	Rank
	1	2	3	4	5	6	7	8	9	10	11	12	13		
Abscond	12	0	1	0	4	3	0	0	0	0	0	1	2	0.25	1
Drought	0	11	6	0	0	0	0	0	0	0	0	0	0	0.217611	2
Migration	1	5	0	1	0	0	0	0	2	0	0	1	0	0.091093	3
pest and predator	0	0	1	2	0	1	3	0	0	0	0	0	0	0.067814	4
parasite(varroa)	1	2	0	2	0	0	0	0	1	3	0	0	0	0.062753	5
pesticide and herbicide	2	0	0	0	0	2	0	0	0	0	0	1	9	0.046559	6
lack of water	0	0	0	1	1	0	1	0	0	1	0	2	0	0.046559	6
Disease	1	0	1	0	1	1	0	0	0	1	0	0	0	0.045547	8
lack of forage	0	0	0	0	1	2	2	0	2	8	0	0	0	0.044534	9
Death of colony	1	0	0	0	0	2	1	0	0	0	4	0	0	0.040486	10
Decrease price of honey	0	0	1	0	0	2	1	0	2	0	0	5	1	0.038462	11
Increase cost of production	0	1	1	0	0	0	0	0	13	1	0	2	0	0.025304	12
lack awareness	1	0	0	0	0	1	0	0	0	0	0	12	0	0.023279	13

Index = ∑ (13 *for rank 1 + 12* for rank 2 + 11* for rank 3 + 10* for rank 4 + 9* for rank 5 + 8* for rank 6+6* for rank 8+5* for rank 9+4* for rank 10+3* for rank 11+2* for rank 12+1* for rank 13) of specific beekeeping problem divided by = ∑ 13 *for rank 1 + 12* for rank 2 + 11* for rank 3 + 10* for rank 4 + 9* for rank 5 + 8* for rank 6+6* for rank 8+5* for rank 9+4* for rank 10+3* for rank 11+2* for rank 12+1* for rank 13) of all beekeeping problems

4.6. Honey Bee Colony Inspection

The result obtained from the respondents' frequency, 58.9% of respondents were practicing internal and external inspection of the honey bee colonies (Table 9). Moreover, only 25.2% of the respondents frequently inspecting their colonies externally but the rest 46.7% and 28.1% of them inspecting sometimes and rarely, respectively(Table 9). About25.2% of the respondents frequently inspecting their colonies internally but the rest 51.4% and 23.4% of them were inspecting sometimes and rarely, respectively (Table 9). Though, colony and the apiary inspection are very crucial to maintain honey bee colonies from different natural risks and enemies such as pests, predators, diseases and chemical poisoning. Experiences show that the external colony inspection can be done frequently at anytime; however, circumspection should be conducted during internal colony inspection. Efficient and continues training and follow up for beekeepers should be considered necessary Abebe Mitkie (2017).

Table 9: Frequency of internal and external hive inspection by the beekeepers in Metema district (n=107) in 2019-2020

Parameter	Variables	Frequency	Response (%)
Do you visit and inspect beehive and colony	Yes	63	58.9
	No	44	41.1
Internal inspection	Frequently	27	25.2
	Some times	50	46.7
	Rarely	30	28.1
External inspection	Frequently	27	25.2
	Some times	55	51.4
	Rarely	25	23.4

4.7. Survey Results of Varroa mite

4.7.1. Varroa mite (locally called "Yenib Mezeger")

Varroa mite, as one of the major honey bee parasite in this the study area, 55.1% of the respondents have claimed as one of the factors responsible for colony number decreasing trend (Table 10). In this case, the parasites has ranked 5th among the group in its importance (Table 8). More specifically, these parasites are causing the considerable amount of damage through colony weakening. However about 44.9% of beekeeping respondents claimed that they didn't know the impact of the pest on their honey bee colonies (Table 10).

4.7.2. Varroa incidence and infestation

As it has been indicated in (Table 9) 44.9%of respondents have never observed/noticed Varroa mite in their colonies while, 55.1% of the total respondents observed Varroa mite in their colonies and have noticed its infestation (Table 10). This result disagree with Alemu Tsegaye *et al*. (2015) who reported that (54.5%) have never observed Varroa mite in their colonies while 45.5% of the total respondents observed varroa mite in their colonies in South Wollo, Waghimra Zone Amhara Regional State, Ethiopia. Moreover, this the survey data has explained that infestation rate of the colonies with this pest has considerably increased in the last three years 2016 – 2018 (Table 11).

Table 10: Varroa mite observation in the colonies of the respondents in Metema district (n=107) in 2019-2020

Parameter	Variables	Frequency	Response (%)
Have you observed varroa mite in your colony?	Yes	59	55.1
	no	48	44.9
	Total	107	100

Table 11: Mean number of colonies infested by the varroa mites within three years in Metema district (2016-2018) in 2019-2020

Years	Traditional hive	Transitional hive	Modern hive
2016	0.48	0.39	0.36
2017	0.51	0.49	0.55
2018	1.25	0.91	0.56

As indicated in the (Table 12) 40.2%of the respondents explained that their colonies had started to suffer from varroa mite infestation within these recent years from 2015-2020. This might be related to high mobility and the marketing of honey bees for the transfer of colonies from traditional to the modern hive promoted by the extension program. However, for some respondents, the time when the respondent of the beekeepers started to notice mites on the bees were traced back during 2009-2014 and 2003-2008, supported by 32.7% and 27.1% of the respondents, respectively (Table 12). This shows that the varroa mite were introduced in to the study area some years back without being noticed by the majority of the beekeepers in the representations and increase years to years infestation of the honey bee colonies. The presence of the Varroa mite was first detected in 2008 when the conducting nationwide the diagnostic survey in Ethiopia (Abebe Jenberie *et al*., 2010). Likewise the presence of the Varroa mite in the Kenya was first detected in 2009 (Muli et *al*., 2014).

These newly introduced pests to Africa might have the long term of implications for the honey bees populations. As these new parasites become more widespread, as pesticide use increases and as the land of escape degradation increases due to increased the urbanization and climate change of expect to see the combination of all these factors negatively impact the bees colonies in the future.

Table 12: The respondent colonies start to suffer from the varroa mite infestation in Metema district (n=107) in 2019-2020

Parameter	Variables	Frequency	Response (%)
Since when did your colonies start to suffer from the varroa mite infestation?	2003-2008	29	27.1
	2009-2014	35	32.7
	2015-2020	43	40.2

4.7.3. Behavioural change of colonies by the varroa mites

The most common behavioural changes as a result of varroa mite infestation reported by interviewed the beekeepers were ,reduce cleaning behaviour(27.6%)and aggressiveness(22.9%) reduce productiveness(20.0%) ,reducing strength behaviour (15.2%) and reduced foraging activity(14.3%), of the respondents respectively (Figure 9) . Furthermore, increased effect of varroa mite on honey bee absconding tendency, irregular brood pattern, colony dwindling, loss of colony , deformed wing and disturbance colony were also observed the effected among varroa infested colonies supported by 28.0%, 18.7% and 17.8% and also rank (1st,2nd and 3rd) of interviewed respondents respectively (Table 13). The Symptoms of varroa mite infestation in the colony may include restless behaviour, spotty brood patterns, and discarded pupae at the hive entrance, malformed and discoloured and drones (MAREEC, 2004). Detection of dead pupae with discoloured, shrunken and decreased the body size was reported by Desalegn Begna(2015).However in this particular study, it was not confirmed in the monitoring apiaries for any signs of this syndrome within the observed period. Therefore the presence of parasitic mite syndrome has to be confirmed by the experimental evidence through the prolonged monitoring period.

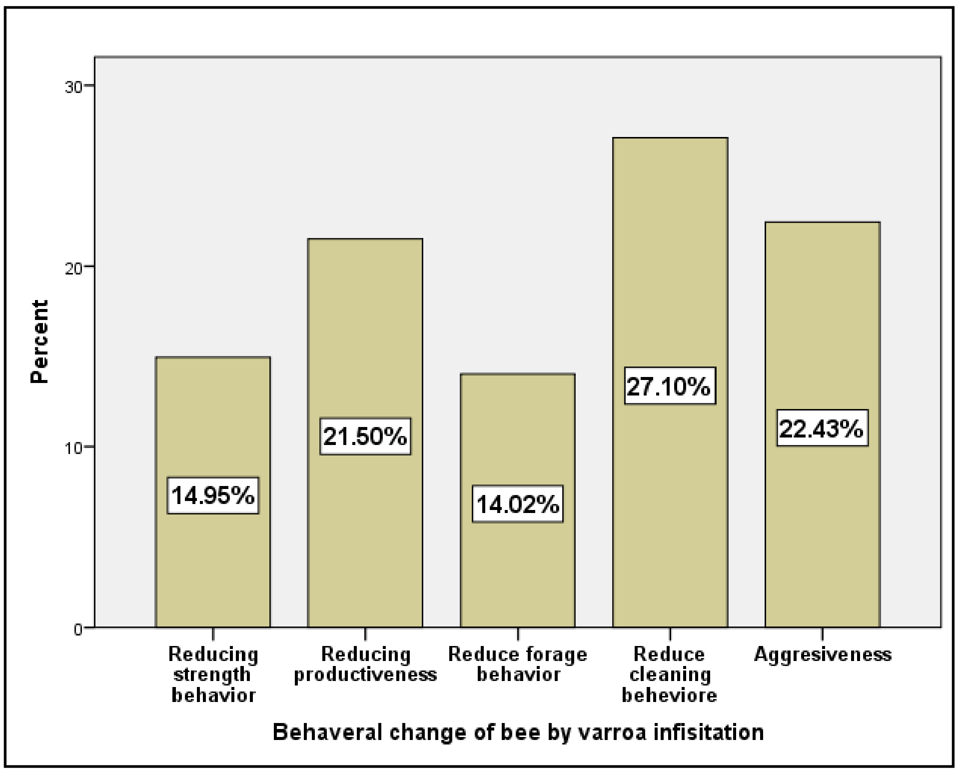

Figure 9: Behavioural change of colony by varroa mites (2019-2020)

Table 13: The effect of varroa mite on the colonies with rank in Metema district (n=107) in 2019-2020

Parameter	Variable	Frequency	Respondent (%)	Rank
Effect of varroa mite on the colonies	Absconding	30	28.0	1
	irregular brood pattern	20	18.7	2
	colony dwindling	19	17.8	3
	loss of colony	15	14.0	4
	deformed wing	14	13.1	5
	disturbance colony	9	8.4	6

4.7.4. Time of varroa mite occurrence

The majority of beekeepers involved in this study reported that they (53.14%)and some others (30.84%, 8.41% and 5.61%) have observed varroa mite in their colonies during the time from March – May , June-August ,December-February and September-November in most cases when colonies were starved respectively(Figure 10).Weakened colony due to the prolonged dearth period from March – May and also June -August the mite was detected the local colonies. The observation the time reported by the beekeepers (March - May) was found to be different from the seasonal monitoring of this result which was higher at active season with a peak at November. The difference might be due to the beekeepers frequently observing their colonies when they are less defensive at dearth period than their defensive the time (active season).

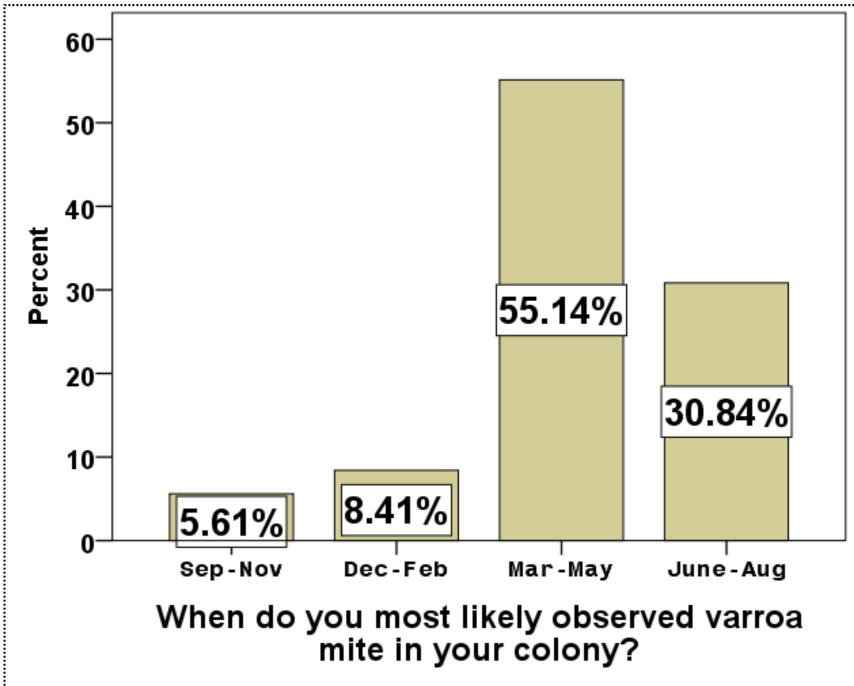

Figure 10: Time of varroa mite occurring (2019-2020)

4.8. Diagnosis Result of Varroa mite

4.8.1. Adult bee diagnosis

This study showed that all the sampled Kebeles and apiary sites were tested positive to *varroa* mites with 100% infestation rate. On the other hand, from the total 96 honey bee colonies diagnosed varroa mites were detected in 71 with overall infestation rate of 73.96%. This result almost agrees to Desalegn Begna (2014) and Namayanja, D.*et al.* (2016) who reported that 82% and 75.3% in Tigray Region, Ethiopia and in Uganda, respectively. An average of 291 ± 10 bees per colony were examined through adult bee colonies and an average of 10 ± 2 (ranging from 9-12) varroa mites were recorded. Although there is apparent difference, infestation rates were high for Meka (83.33%), Lemlem Terara (79.17%), Gobayi Jejibet (70.83%). and Kumer Aftiti(62.50%), respectively (Table 14).However, at colony level the average number of varroa mites was high for Kumere Aftiti and low for Lemlem Terara and Gubay Jejibet Kebeles (Table 14).

Table 14Incidence rate of varroa mites to adult honey bees in each kebele in Metema district (2019-2020)

Kebeles	Number of sampled apiary site	Number of apiary sites positive to varroa	Total number of bee colonies sampled	Number of colonies found positive to varroa mite	Incidence rate (%)	number of adult bees sampled per colony	number of varroa mite colony
Meka	2	2	24	20	83.33	300	11
Lemlem Terara	2	2	24	19	79.17	280	9
Kumer Aftiti	2	2	24	15	62.50	285	12
Gubay Jejibet	2	2	24	17	70.83	300	9
Total	8	8	96	71	295.83	1165	41
Average	2	2	24	17.75	73.96	291.25	10.3
STD				2.217		10.308	1.5

Note: STD is Standard division

4.8.2. The brood bee diagnosis

From the total of 96 honey bee colonies diagnosed for brood, 82 honey bee colonies accounting 85.42% of the diagnosed brood were tested positive for varroa mites. The result from the diagnosed brood showed that all the sampling localities were 100% infested with varroa mites with the infestation rate ranging from 75% to 100% at honey bee colony level (Table15).On the average 24 ± 0.00 bee colonies were sampled for brood diagnosis from each Kebeles and an average of 21 bee colonies were found positive to varroa mite. Likewise, on the average 98.25 ± 2.062 brood cells were opened from each bee colony with an average of 8.3 ±2.872 (range from 6-12) varroa mite detection. Through the brood analysis, Lemlem Terara and Kumer Aftiti Kebeles were found with high and low varroa mites infestation rates, respectively (Table 15).

Furthermore, the positive tests of varroa mite diagnosis on drone pupae as well as dead pupae with discoloured, shrunken, decreased body size during the laboratory diagnosis were detected of the disease caused DWV infection associated with infestation of the parasitic mite, *Varroa destructor* (Kovac,1988 and Prisco *et al*., 2011).This is because varroa mite is effective Deformed Wing Virus vectors and bees as well as brood parasitized by varroa mites are nearly 100% infested by Deformed Wing Virus(DWV) Prisco *et al*(2011)and Genersch (2005).

Table 15: Incidence rate of Varroa mites to honey bee brood in each Kebeles in Metema district (2019-2020)

Kebeles	Number of sampled apiary site	Number of apiary sites positive to varroa mite	Total number of bee colonies sampled	Number of found positive to varroa mite	Incidence rate (%)	Average number of opened brood per colony	Number of varroa recovered per colony
Meka	2	2	24	19	79.17	100	9
Lemlem Terara	2	2	24	24	100.00	97	6
Kumer Aftiti	2	2	24	18	75.00	96	12
Gubay Jejibet	2	2	24	21	87.50	100	6
Total	8	8	96	82	341.67	393	33
Average	2	2	24	20.5	85.42	98.25	8.25
STD				2.646	11.023	2.062	2.872

Note: STD is Standard division

So as all the surveyed areas tested found to be positive to varroa mite with infection levels ranging from 62.5% to100 %(Table 14).The result is in agreement with Desalegn Begna (2014*)* and Shimelis Mengistu, *et al*. (2016) who reported that 37.5% to 100% and80% to 92.3% of honey bee colonies were infested with *varroa* mites in Tigray Region, Ethiopia and Toke-kutaye district. The average number of varroa mite recorded from a single bee colony through adults and brood's analyses were 10 and 8 mites, respectively (Table 14and Table 15).The current study suggesting Varroa mites have led to the virtual elimination of local bee colonies and the honey bees are close to collapse concurring with the finding that established more 10 mites natural drop per day can cause colony collapse (Boecking and Genersch, 2008). However, the causes of variations in infestation rates among the studied Kebeles might be attributed to the service level of the places as bee colony marketing points.

On the other hand, the wide distribution of the varroa mites in all the surveyed areas and in all inspected bee colonies indicates the long time introduction. Higher infestation rate of the varroa mite observed in the apiary might be associated with contact among colonies in the apiary found close to each other, hence facilitate transmission of varroa mite among the colonies through swarming and drifting (Somerville,2007). The chance of bees in apiary to visit the same flower is higher than bees in backyard. However, the causes of variations in infestation rates among the studied selected Kebeles, it be established the infestation was due to poor hive management or climatic factors or related to the geographical location and service level of the places as bee colony marketing points. On the other hand, it is not certain how and when these mites invaded the honey bee colonies of *Apis mellifera* in the country especially in the districts where the mites were found.

The presence of *Varroa destructor,* a parasitic mite could be major honey bee health problem cause the decline in colony establishment and are a major problem for kept bees in apiaries (Hunt, 1998).

4.9. Incidence rate of Varroa mite

The incidence rate of varroa mite was also found to be higher in bees kept in the adult bees (71%) than bees kept in the brood bees (Table 16). However, statistically significant differences (χ 2 =0.046; p<0.05) were observed among varroa mite incidence rate in the adult bee colony and brood. Furthermore, the higher varroa mite incidence rate observed in adult bee colonies might be associated with the different contacts among colonies and the introduction of unknown sources of colonies for transferring to the modern hives. In most cases beekeepers sell colonies with inferior in their performance and/or weakened by parasites infestation. As a result of the introduction of such types of honey bee colonies in the apiaries, the distribution within the apiaries increased. Colonies who were arranged very close to each other in the apiaries have been believed to facilitate transmission of varroa mite among the colonies through swarms, drifting and robbing activities. Beekeepers probably spread an infestation from one colony to another through frequent apiary manipulations.

Infestations also are spread as a result of drifting (especially drifting drones) from one apiary to another and swarming bees (MAREEC, 2004). In regions with a high density of honey bee colonies the population dynamics are influenced by a permanent exchange of mites when foragers or drones enter foreign colonies or by robbing (Goodwin et al., 2006). It is interesting to note that the robbing bees will "receive" the mites from the victim colonies, which often are already weakened through a high Varroa infestation, and that the effective "robbing distance" is more than 1 km (Renz and Rosenkranz, 2001).

Table 16: Binary logistic regression for factors influencing incidence rate of varroa mite in Metema district (2019-2020)

Variable	B	SE	Wald	DF	Sig.	Exp(B)
Incidence rate of Adult bee vs brood bee	0.638	0.203	9.840	1	0.002	0.529
Colonies lose of adult bee vs brood bee	1.241	0.232	28.662	1	0.000	0.289

Hive type of traditional vs modern hives	0.638	0.203	9.840	1	0.002	0.529
Hive type of transitional vs modern hives	0.638	0.203	9.840	1	0.002	0.529
Active season of adult vs brood bee	1.738	0.271	41.116	1	0.000	0.176
Dearth season of adult vs brood bee	1.814	0.278	42.427	1	0.000	0.163

Nagelkerke R square =0.64, x2=0.046: Significant at $p<0.05$ and $p<0.01$: (n=107)

From the total of 96 honey bee colonies examined for infestation of Varroa mites in adult bees, the prevalence recorded during active period and dearth seasons was81 (84.4%) and 77 (80.21%), respectively (Table 15). From the total of 96 honey bee colonies examined, 89(92.71%) were positive to Varroa mites in the sealed brood (Table 17)

Table 17: Colony level incidence rate of varroa mites in four selected in Metema district (2019-2020)

Study Kebeles	Varroa mites in adult bees					Varroa mites on brood cells during active season		
	Seasons					Samples	Positive	%
	Active period			Dearth period				
	Samples	positive	%	positive	%			
Meka	24	21	87.5	20	83.3333	24	24	100
Lemlem Terara	24	20	83.3	21	87.5	24	21	87.5
Kumer Aftiti	24	18	75	16	66.667	24	20	83.33
Gubay Jejibet	24	22	91.7	20	83.33	24	24	100
Overall	96	81	84.4	77	80.208	96	89	92.71
Average		20.25		19.25			22.25	

The result from the sample showed that Kebeles were heavily infested with Varroa mites in both adult bees and brood analysis. The causes of variation in prevalence among the studied Kebeles might be attributed to different factors such as ecological variability, season and management aspects. Alattal *et al*. (2006) explained that the prevalence variation among localities is the product of interaction between several factors including ecological factors, bee type and Varroa mite dynamics. In the current study, the highest prevalence in the four Kebeles might be attributed to their honey bee colony movement and colony marketing places for most of the other Kebeles. The overall prevalence in this finding is slightly lower than reports previously by Desalegn Begna (2015) in Tigray region, who reported that all the surveyed areas tested positive to varroa mite with 82% of prevalence. The distribution rate of Varroa mites in African countries were, 89.5% infected apiaries with 85 % colony level prevalence in Kenya (Muli et al., 2014), in East Africa (Kenya, Tanzania

4.10. Infestation rate of varroa

Concerning to the infestation rate of varroa mite on adult bees per hundred bees calculated in colonies located in Moreover, the honey bee colonies brought to new apiaries have been observed to be more prone to varroa mite infestation. Similar higher varroa infestation rates were observed from traditional hive (4.25%) in a phoretic phase (Table 18). This result disagreement with Alemu Tsegaye *et al*., 2015 who reported that Trsitional hive and modern hive high infestation in South Wollo and Waghimra Zones of Amhara Region, Ethiopia .The mean infestation rate of adult bee and brood bees in the study area 3.378±0.296 and 7.699±1.466 was recorded respectively (Table 18 andTable19). From the brood cells in also traditional hives high infested (Table 18). Lower varroa mite infestation rate of in modern hive in both adult and brood bees than the other two hive types might be associated with the frequent removal or cutting of the combs might reduce the residues of the pathogen or break the life cycle of the agent.

Behavioural adaptation of bees for frequent swarming due to overcrowding of its small volume of traditional hive which favours reduction of its varroa load along with the departed daughter colonies. When we calculate the number of varroa mites per hundred bees in honey bee colonies from the two Kebeles (Meka and Kumer Aftiti), higher infestation rate was observed in brood and adult bee colonies (Table 18and Table 19)

Table 18: Mite infestation rates per hundred adult bees of the different variables during the study in Metema district (2019-2020)

Variables	Adult bees sampled	Varroa mite covered/ sample of bees	Infestation rate= (varroa mite covered/ sample of bees)*100
Traditional hive	400	17	4.25
Transitional hive	400	13	3.25
Modern hive	365	11	3.0134
Total	1165	41	10.515
Mean±SE	366.25±23.57	12.5±1.71	3.378±0.296
Minimum	300	11	3
Maximum	400	17	4
Selected kebeles			
Meka	300	11	4
Lemlem Terara	280	9	3
Kumer Aftiti	285	12	4
Gubay Jejibet	300	9	3
Total	1165	41	14
Mean±SE	291.3±5.2	10.3±.8	3.5±.3
Minimum	280	9	3
Maximum	300	12	4

Table 19: Mite infestation rates per hundred brood bees of the different variables during the study in Metema district (2019-2020)

Variables	brood bees sampled	Varroa mite covered/ sample of bees	Infestation rate= (varroa mite covered/ sample of bees)*100
Traditional hive	134	14	10.44776
Transitional hive	147	8	5.442177
Modern hive	111	8	7.207207
Total	393	32	23.09714
Mean±SE	130.67±10.53	10.00±2.00	7.699±1.466
Minimum	111	8	5.44
Maximum	147	14	10.45
Selected kebeles			
Meka	100	9	9
Lemlem Terara	97	6	6.18556701
Kumer Aftiti	96	12	12.5
Gubay Jejibet	100	6	6
Total	393	33	33.68556701
Mean±SE	98.25±1.031	8.25±1.44	8.42±1.52
Minimum	96	6	6.2
Maximum	100	12	12.5

4.11. The occurrence of varroa mite for selected Kebeles

In this survey, the occurrence of Varroa mite has been observed in the selected Kebeles area. Out of the 4 sampled Kebeles in the Metema district, all of them (100%)were found to be varroa positive indicating a wide spread in many areas of the Kebeles(Meka(83.33%),Lemlem Terara(79.17%),Gobayi Jejibet (70.83%) and Kumer Aftiti(62.5%),respectively (Table 15)where beekeeping is in-practice. In this study, the varroa mite occurrence (84.38%, 75% and 62.50%)

was observed in traditional, transitional and modern hives respectively (Table 20). From the total colonies examined (96) for the presence of varroa mite, the laboratory diagnosis has confirmed that 73.96% (71) were found to be varroa mite infested.

The present result was found to be comparable with a findings of Muli *et al*. (2014), who reported 83% varroa mite prevalence in Kenya and Desalegn Begna (2014) who has also reported 82% varroa prevalence in Tigray region, Ethiopia. This result is compared with also higher than 56% prevalence at colony level reported by Allisop (2006) in South Africa and 48% prevalence reported by Zee *et al*.(2015) in Tanzania

Table 20: The occurrence of varroa mite in selected Kebeles with hive types in Metema district (2019-2020)

Types of hive	Samples				
	Total(n)	Positive(n)	Positive (%)	Negative(n)	Negative (%)
Traditional	32	27	84.38	5	15.663
Transitional	32	24	75.00	8	25.00
Modern	32	20	62.50	12	37.50
Total	96	71	73.96	25	26.04
Average	32	23.67	73.96	8.33	26.04
Kebeles					
Meka	24	20	83.33	4	16.67
Lemlem Terara	24	19	79.17	5	20.83
Kumer Aftiti	24	15	62.50	9	37.50
Gubay Jejibet	24	17	70.83	7	29.17
Total	96	71	73.96	25	26.04
Average	24	18	73.96	6	26.04

4.12. The abundance of *Varroa destructor* in different hive types

Varroa destructor, the parasite of honey bee, is the most devastating pest mainly threatening bee keeping industry all over the globe (Allsopp ,2006; Gulati, Thakur, and Giroh, 2013). Abundance/intensity of Varroa destructor infestation in the honey bee colony is more important factor to establish its management level in honey bee colonies (Delgado *et al*, 2012; Okosum, 2013). The intensity (Number of varroa destructor/100 bees) was compared in three hive types: Traditional, Transitional and Frame (Table 21).The result showed that, there is significant variation (T = 13.681, P=0.001) in abundance/intensity of the mite among hive types. The overall mean of *Varroa destructor* load was shown to be 5.920±0.432 remaining well above maximum of mites/100 bees, the standard management range which is 2 mites/100 bees (OIE, 2011) indicating that honey bees are perhaps affected by infestation of the mite in the studied honey bee colonies.

Table 21: Mean comparison of *Varroa destructor* load in different hive types in selected Kebeles in Metema district in 2019-2020

Hive types	N	Mean ± SE	95% CI		Df	T	Sig.
			Low bound	Higher bound			
Traditional	32	6.75±0.479	5.62	7.88	1	13.681	.001
Transitional	32	6.00±0.408	5.04	6.96			
Modern	32	5.00±0.408	4.04	5.96			
Overall mean	96	5.920±0.432	4.9	6.93			

CI = Confidence interval, T = T-value, Sig. = significance value; N = Number of sample; SE= Standard error for mean

Chapter 5: CONCLUSION AND RECOMMONDATION

5.1. CONCLUSION

This study was conducted in four selected “*Kebeles”* in Metema district North Western, Amhara Regional State and during the time between October 2019 to March 2020 to identify the incidence of Varroa mite in local honey bee colony and to determine Varroa mite infestation rate in local honey bee colony. This study revealed that the presence of real threat to beekeeping from varroa mite infestation. The high infestation rate of the varroa mite in all sample “*Kebeles”* show that there have been negative health consequences and declined honey bees colonies as the varroa mites were moving easily to higher mobility and swarm catching with less or no any cautions. It is difficult to trace how and when it was introduced in Ethiopia. The presence of varroa mite in the country is highly significant and market oriented mobility of honey bee colony coupled with lack of awareness provided to the beekeeper about its high rate of distribution. So the higher infestation rate of varroa mite especially greater than 5 mites per hundred bees alarmed to the local honey bee colonies need close monitoring as infestation levels greater than 10 mite per hundred bees could result the colonies collapse in study area ((Boecking and Genersch, 2008).

5.2. RECOMMONDATION

From the above conclusion, the following recommendations are forwarded for future research and development of beekeeping and honey bee health.

⇒ Honey bee colony seasonal management practices including apiary cleaning and strengthening, regular colony internal and external inspection and disease diagnosis shall be considered and advocated as potential possible solution to minimize honey bee death and decline due to honey bee parasite and diseases.

⇒ Awareness creation using public mass –media and possible methods to advise all actors in the value chain to take important caution while performing bee colonies purchasing, swarm catching, and transporting from doubtful to minimize bee sources parasite and disease fast spread.

⇒ Strong national or Regional enforcement that could be regulated the illegal colony movements and marketing should be in place as soon as possible to hold parasite and minimize the threat and posed to the market growth of the sector.

⇒ Training on varroa mite diagnosis and monitoring, its economic importance and means of reducing its transmission and spread, should be also given to different actors.

⇒ Research agenda should be developed and promoted before mite population densities reach the threshold levels in each part of country and agro-ecology.

⇒ Use non-chemical varroa mite control option like screen bottom board, sanitation, drone brood removal, re-queen with resistant stock, use powder sugar method, should be tested and verified though research in accordance with the local prevailing conditions.

⇒ If the apiculture subsector to continue playing its purposive roles, there must be paradigm shift from traditional system to improve ways of beekeeping that enables as beekeeper easily diagnose and medicate to subdue the effects of varroa mite and also other emerging disease of honey bees.

⇒ Problem solving research should be launched to define seriously varroa infested and free areas of the country with parallel setting up of controlled varroa mite on local bees' colonies in the country.

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APPENDICES

7.1. Appendix questionnaire for the study

Bahir Dar University

College of Agriculture and Environmental Sciences

School Of Animal Science and Veterinary Medicine

Graduate Program

Incidence and Infestation Rate of Varroa Mite (*Varroa Destructor*) On Local Honey Bee Colony in Metema District, North Western, Amhara Regional State, Ethiopia

Questionnaire

Date of interview ____________

1. Region _____________ 1.2. Zone ______________ 1.3. Woreda -------

1.4. PA/Kebele ______________ 1.5. Village (Got) ------------

Part 1.Household characteristics1.1. Name of the respondent ----------------------------------

1.2. Sex: 1= Male 2= Female

Age: 1= 18-30 2= 31-45 3= Above 45

1.3. **Marital status** 1. Single 2.Married 3.Divorced 4.Widow 5. Widower

1.4. **Education of the interviewee**

1= Illiterate 2= Can read and write 3= Primary education (1-4) 4= Junior (5-8) 5= Secondary education (9-12) 6= College

7. Other (specify) - -------------------------

1.5. Number of family members: 1= below 5= 6-12 3= Above 12

1.6. **Religion of the household**

1= Orthodox___________________2= Muslim ---

1.7. Do you own livestock? 1=Yes 2=No

If yes, what type of livestock you have?

Livestock specie	Cattle	Sheep	Goa	Poultry	Donkey	Mule	Camel	Remark

s			t					(
No								

1.8. Do you own land? ? 1=Yes 2=No

If yes what is the size of land holding (hectare) 1= below 1 2=above

1.9. What are the major crops grown in your area?

I. Teffe 1=Yes 2=No
II. Maize 1=Yes 2=No
III. Sorghum 1=Yes 2=No
IV. Sesames 1=Yes 2=No
V. Cotton 1=Yes 2=No
VI. Vegetables 1=Yes2=No
VII. Fruits 1=Yes 2=No

<u>Part2. Beekeeping Activities</u>

2.1 Do you keep honey bees? (1. Yes 2. No

2.2. For how long do you keep bees and practiced beekeeping? a. More than 15 year's b. 10 – 15 Years c. 5 – 9 years d. 1 – 4 Years

2.3. How do you start beekeeping for the 1st time? Source of bee a. Gift from parents b catching swarming bee c. buying d. robbing from caves and forests) e. Other (specify) --

2.4. What are the driving forces to engage in beekeeping practices? a. Income b. Home consumption c. Both 1 & 2 d. Others (specify) _________________

2.5. If you use for home consumption, List the home use of honey.

15.1. As a food a. Yes _________ b. No _________

15.2. As a medicine a. Yes _________ b. No) __________

15.3. For beverages a. Yes _________ b. No __________

15.4. For cultural and ritual ceremonies a. Yes _________ b. No __________

15.5. Others (specify): ______________________________________

2.1. No of colonies owned, honey & beeswax yield per year in kilogram.

No	Hive types	Year					
		2016/2008	2017/2009	2018/2010	2019/2011	2020/2012	Remark

		Colony	Honey	Wax	Colony	Honey	Wax	Colony	Honey	wax	Colony	Honey	Wax	Colony	Honey	Wax	
1	Traditional																
2	Movable frame																
3	Transitional																

2.1.1. Which type hive use most of time? A. Traditional-------------------year(s).b.Movable frame--------------------year(s) c.Transitional-----------------------------year(s)

2.2. Where do you keep your bee colonies?

1=Backyard 2= Inside house 3=Closure areas 4= Hang on trees 5=others (specify)

2.3. How many hive site your keep places?

No	Site or placement of hive	Traditional	Transitional	Moveable- frame
1	Backyard			
2	Under the eaves of the house			
3	Inside the house			
4	Hanging on trees near homestead			
5	Closure areas			
6	Hanging on trees in forests			
7	Others (specify)			

2.10 For how many years your colony remains or stays in the hive?

No	Status of survival	Traditional	Movable frame	Transitional
1	Minimum(years)			
2	Maximum (years)			

2.11 Does absconding occur in your bee colony? 1= Yes 2= No

2.11.1 If yes, list the number of absconded hives you have:

2.11.2 What are the major causes for absconding? 1= Forage scarcity 2= pests &predators

No	Types of hive	Unit	2012/2020	2011/2019	2010/2018	2009/2018	2008/2017	Total
1	Traditional	No						
2	Movable frame	No						
3	Transitional	No						
	Total	No						

3= disease &parasites 4=.Weather5.Others (specify) -----------------------

2.12 What is the trend of your bee colony number? 1= decrease 2= increase3= no change

2.13 What is the trend of your bee colony honey yield? 1= decrease 2= increase 3= no change

2.13.1. If there is a decrease in trend in the number of bee colonies and honey yields over the year, what are the causes in order of importance?

No	Cause	Rank
1	Lack of bee forage	
2	Lack of water	
3	Drought	
3	Migration	
4	Absconding	
5	Pests and predators	
6	Parasite	
7	Diseases	
8	Pesticides and herbicides Application)	
9	Death of colony	
10	Decrease in price of honey	
11	Increased cost of production	
12	Luck of credit	
13	Others (specify)	

2.14 What are the major pests and predators found in the area that threat your colonies? List in order
Of importance

No	Pests and predators(common name)	Local name)	Rank	Season of occurrences	Effect	Local control
1	Ants					
2	Wax moth					
3	Bee lice/mites)					
3	Beetle					

4	Spiders					
5	Wasps					
6	Prey mantis					
7	Toads					
8	Lizard					
9	Snake					
10	Monkey					
11	Birds					
12	Varroa mite					
13	Hamagot /Shelemetmat					
14	Others (specify)					

***Effect= 1.colony dwindle 2.colony death 3.Absconding 4. Direct honey loss**

2.15 Do you observe any honey bee diseases in your apiary? 1. Yes 2.No

2.15.1 If yes, what are the diseases you observed?

No	Local name	Stages of affected		Symptoms	Incidence period	Effect	Local control
		1.Adult	2.Brood				
1							
2							
3							

***Effect= 1.colony dwindle 2.colony death 3.Absconding4. Direct honey loss**

2.15.2. In which hives your colonies do more likely affected by the diseases?

No	Types of hive	Response	If yes put reasons
1	Traditional	1.yes 2.no	
2	Movable Frame	1.yes 2.no	
3	Transitional	1.yes 2.no	

2.16 Which of your colonies were more likely to be infected by the above factor? -----------------------

1= Strong 2=Weak 3=Medium 4= All

2.17 What are the Behavioural characteristic features of your honey bees?

1=Docile 2=Medium3=Aggressive

2.17.1 Which one is productive in terms of honey production?

1=Docile 2= Medium 3=Aggressive

2.17.2 Which one is more defensive against any pests and diseases?

1=Docile2=Medium 3= Aggressive

2.17.3. Have you ever observed varroa mites in your colony? a. Yes ______ b. No______

2.17.4. If yes indicate number of honey bee colonies infested by varroa mite over the last 5 yrs.

Hive types	No. of colonies infested with varroa mite					Remark
	2008/2016	2009/2017	2010/2018	2011/2019	2012/2020	

Traditional						
Modern						
Transitional						

2.17.4.1. Since when did your colonies start to suffer from Varroa mite infestation_______________?

2.17.5. Effects of varroa mite

Year	Irregular brood pattern	Affected adult bees	Absconded	Dwindled	Died death	Infected not yielded	Deformed wing	Disturbance of colonies	Remark
2016									
2017									
2018									
2019									
2020									

2.17.6. Average honey yield /yr. with regard to varroa mite infestation

1. Infested _____________ Traditional __________ Transitional _____________ Modern ______________
2. Uninfected __________ Traditional _________ Transitional ___________ Modern ____________

2.17.7. Condition of honey bee colonies before & after infestation;

1.17.8. Which of your colonies most likely infected by disease and pests?

No	Condition of colony	Disease	Pest	Varroa mite	Remark
1	Strength	1.strong ☐	1.strong ☐	1.strong ☐	
		2.medium ☐	2.medium ☐	2.medium ☐	
		3.weak ☐	3.weak ☐	3.weak ☐	
2	Defence behaviour	1.dicile ☐	1.dicile ☐	1.dicile ☐	
		2.agressive ☐	2.agressive ☐	2.agressive ☐	
		3.very aggressive ☐	3.very aggressive ☐	3.very aggressive ☐	

2.17.9. Have you observed any change of behaviour on infected colonies? 1. Yes 2. No

No	Behavioural change	Disease	Pest	Varroa mite	Remark
1	Irregular brood pattern	☐	☐	☐	
2	Disturbance of the colonies	☐	☐	☐	

3	Dead bees and brood on the entrance				
4	Weakened colonies				
5	Absconding				
6	Infested and not yielded				
7	Reduced foraging activity				
8	Loss of the entire colony				
9	Productivity				
10	Other specify				

2.17.10. Which types of bee keeping system is most likely affected by Diseases and pests?

	Beekeeping system	disease	Pest	Varroa mite	Remark
1	Traditional				
2	Movable frame				
3	Transitional				
4	1+2				
5	1+3				
6	2+3				

1.17.9. When do you most likely observe bee disease & enemies in the colony?

No	Beekeeping system	Disease		Pest		Varroa mite		Remark
		observe	No	observe	No	Observe	No	
1	Traditional							
2	Movable frame							
3	Transitional							

1.17.10. Which season most infected your colony?

No	Active period	Dearth period

2.17.12. What measure have you taken to control varroa mite, disease, pest & predators?

Types of measurement	Disease	Pest	Varroa mite	Remark
Traditional				
Modern				
Management				
Others specify				

2.17.13. Have you faced a problem of absconding? a. Yes b. No

. If yes, number of honey bee colonies absconded from the total colony owned/year 1. One 2.Two 3.Three 4.Four 5.Five 6.Six - Ten 7.>10

. If yes, in which month does absconding occur? (Circle one or More Months) 1. January 2. February 3. March 4. April 5. May 6. June 7. July 8. August 9. September 10. October 11. November 12. December

.What do you think the reason for absconding? 1. Shortage of food 2. Bee Enemies 3.Lack of shelter 4. Poor bee management

2.18 What is the average honey yield of a colony in a year?

2.18.1. Infected _________________ Kg/hive

2.18.2. Uninfected _______________Kg/hive

2.19 What abnormality have you observed in the combs in the infected colonies?

____

2.20 Do you think that the infected colony affects the other healthy colonies? 1=Yes 2=No

2.20.1 If yes, what are the transmission mechanisms? 1=Materials 2= Honey 3= Robbing 4=Wind 5.Common feeding 6=others (specify) --------

Part 3. Bee colony management and honey

3.1 Do you visit and inspect your beehives and colonies? 1. Yes____2. No_____

3.1.1 If yes, which type of inspection you perform?

3.1.2 External hive inspection 1. Yes_____ 2. No______

3.1.3 Internal hive inspection 1. Yes _____ 2. No______

3.1.4 Frequency of inspection

3.1.4.1 External hive inspection: (circle one or more)

1. Frequently 2. Some times 3. Rarely

3.1.4.2 Internal hive inspection: (circle one or more)

1. Frequently 2. Some times 3. Rarely

3.1.2 If no inspection, what is the reason? ______________________________

3.2 Do you clean your apiary? 1. Yes 2. No

If no why? ____

3.3 When the following major activities occur in your locality?

No	Major activity	Season(s) of occurrence
1	Brood rearing period	
2	Colony Swarming	
3	Colony Migration	
4	Colony Absconding	
5	Honey flow season	
6	Honey harvesting time	
7	Dearth period	

3.4 Do you feed your honey bee colonies? 1. Yes 2. No

3.4.1. If yes, when do you feed your honey bees? (Months): ____________________
3.4.2. What kind of feed you offer to your honey bees? _______________________________________

3.5. Do you practice migratory beekeeping? 1. Yes 2. No
3.5.1. If yes, what are your reasons for bee colony migration?
1. Crop pollination 1. Yes 2. No
2. Honey production 1. Yes 2. No
3. Fetch of forage and water 1. Yes 2. No
4. Disease control 1. Yes 2. No
5. Agrochemicals prevention 1. Yes 2. No
3.6 Where do your honey bees get water?
1=Pond 2=Running river 3= Stagnant water 4=Watering 5= others (specify) -----
3.7 Does swarming occur in your colonies or locality? 1= Yes 2=No
3.7.1. If your response is yes, how many swarms per colony? _____________________________
3.7.2 How many of the swarmed colony is splitted for the next generation? ________
3.7.3 When does swarming occur more frequently? (Months)-------------------------------
3.7.4 Is swarming advantageous to you? 1. Yes 2. No
3.7.4.1. If yes, describe the reason(s)
1. To increase my number of colony 1. Yes 2. No
2. to sale and get income 1. Yes 2. No
3. To replace non-productive bee colonies 1.Yes 2.No
4. Others specify: ____
3.7.3.1. If No, describe the reason____
3.9 From where do you get the beeswax? 1=Own 2=Market 3=Woreda input 4=Teje House 5=No use 6=others (specify) --------------------------
3.9.1 How do you evaluate its quality? 1. Good 2.Bad
3.9.2 If bad, what was the effect? ____

7.2. Appendix List of Tables

Appendix Table 1: Sex with selected kebeles beekeeper count male and female

Parameter		Kebele				
		Gubay Jejibet	Kumer Aftiti	Lemlem Terara	Meka	Total
Sex	Male	17	23	26	31	97
	Female	4	2	3	1	10
Total		21	25	29	32	107

Appendix Table 2: Sex with age in each kebeles

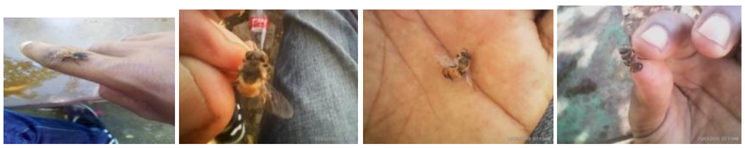
Parameter		Kebele				
		Gubay Jejibet	Kumer Aftiti	Lemlem Terara	Meka	Total
Age	18-30	4	17	13	12	46
	31-60	16	4	13	16	49
	>60	1	4	3	4	12
Total		21	25	29	32	107

Appendix Table 3: Beekeeper Samples from each selected kebeles

Parameter		Sample	Percent	Valid Percent	Cumulative Percent
Valid	Gubay Jejibet	21	19.6	19.6	19.6
	Kumer Aftiti	25	23.4	23.4	43.0
	Lemlem Terara	29	27.1	27.1	70.1
	Meka	32	29.9	29.9	100.0
	Total	107	100.0	100.0	

7.3. Appendix figure

Appendix Figure 1: Discussing with beekeeper about varroa mite during 2020



Appendix Figure 2: Observed in the cause of field dead bee by varroa mite during 2020

Appendix Figure 3: Observed varroa mite on the field bees during 2020

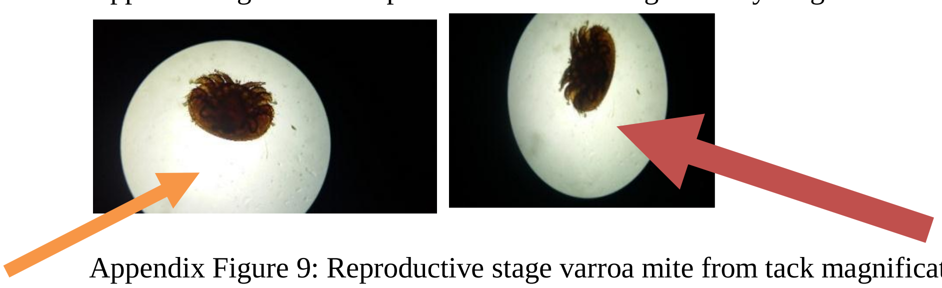
Appendix Figure 4: Observing varroa mite at night time on the honey bee colonies during 2020

Appendix Figure 5: Alcohol washes method for varroa mite examination on adult bees during 2020

Appendix Figure 6: Founding Varroa mite on the adult bee during 2020

Appendix Figure 7: Laboratory diagnosis of varroa mite in Metema animal health class room during 2020

Appendix Figure 8: Group of varroa mite during library diagnosis 2020



Appendix Figure 9: Reproductive stage varroa mite from tack magnification microscope in different body position during 2020

Appendix Figure 10: Measure comb and cut 5cm by 5cm during 2020

Appendix Figure 11: Removed drone & worker brood from sealed comb during 2020

Appendix Figure 12: Varroa mite from the drone and worker brood bee during 2020

Appendix Figure 13: Compared mite and brood (left side) dead pupae with discoloured, shrunken, decreased body size (right side) during 2020

Appendix Figure 14: Collected, Count Brood and compare with reproductive varroa mite (left side) and recorded my note book (right side) during 2020

BIOGRAPHY

I was boron 24th of February, 1990in Ayikel Town, Chilga Woreda, which is located in North Gondar Amhara Regional State, Ethiopia. At 10th years of my age, I started my formal school and studied my Elementary and junior education at Chonchok Elementary School. In 1998, I passed the grade Eight National Exam for Joining Ethiopian High School Education. Then, I moved to a town called Ayikel where I joined high school (9-10) and Preparatory (11-12) education from September 2007 to June 2010. On 29th of January, 2011, I joined Jigjiga University the College of Dry Land Agriculture and graduated with Bachelor of Science degree in Animal and Range Sciences on 29th Juneof 2013. Then I was employed in Metema Woreda Livestock office to work as Bee expert effective from October 10, 2014. In 2019, I joined Bahir Dar University, College of Agriculture and Environmental Sciences, School of Graduate Studies to pursue Degree of Master of Science in Apiculture on February 2022.