MEKELLE UNIVERSITY

Honeybee Production System, Colony Selection Criteria and Performance in Different Agro ecological Zones of Ahferom District, Tigray, Northern Ethiopia

By:

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DECLARATION

I, Tuemay Wendm Mesfin, hereby present a thesis topic entitled "***Honeybee production system, colony selection criteria and performance in different agro-ecological zones of Ahferom district, Tigray, Northern Ethiopia***" for consideration by the Department of Animal, Rangelands and Wildlife Sciences within the College of Dryland Agriculture and Natural Resources at Mekelle University, my thesis in partial fulfillment of the requirement for the Degree of Masters in Apiculture. I sincerely declare that this thesis is the product of my own efforts. No other person has published a similar study which I might have copied, and at no stage will this be published without my acquiescence and that of the Department of Animal, Rangelands and Wildlife Sciences.

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Approval

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List of abbreviations

AM	Anti-Meridian
ANOVA	Analysis of Variance
AWOARD	Ahferom Woreda Office of Agriculture and Rural Development
BoANR	Bureau of Agriculture and Natural Resources
C^o	Degree Celsius
CSA	Central Statistics Agency
EARO	Ethiopia Agricultural Research Organization
ECs	Emulsifiable Concentrates
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FTC	Farmers Training Center
GLM	General Linear Model
HBRC	Holeta Bee Research Center
HF	Holstein Friesian
HH	Household
Kg	Kilo gram
KM	Kilo meter
M	Meter
m.a.s.l	Meter above sea level
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
PM	post meridian
SD	Standard Deviation
SNV	Netherlands Development Organization
SPSS	Statistical Package for Social Science
TLU	Tropical Livestock Unit
US $	United States Dollar
UV	Ultra violet

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Honeybee Production System, Colony selection criteria and Performance in different agro-ecological zones of Ahferom district, Tigray, Northern Ethiopia

ABSTRACT

The study was conducted in Ahferom district, central zone of Tigray, Northern Ethiopia in 2023/2024 to investigate honeybee production systems, honeybee colony selection criteria and colony performance in different agro-ecological zones. Six Tabias were selected purposely to represent the lowland, midland and highlands. A total of 180 sample beekeepers were selected using simple random sampling method. Data were collected using semi-structured questionnaire, field observations, key informant interviews and focus group discussions. The data was analyzed using descriptive statistics and ANOVA using SPSS software (version23). Two types of honeybee production systems. The overall mean number of colonies holding in traditional (4.12) and Modern (0.64) per household beekeepers. Population of worker bees, colour of worker bees, direction of comb building, aggressiveness, honey yield, age of colony, pests and predator resistance, honeybee behavior were the first ten most important parameters of colony selection criteria. Different indigenous knowledge of experiences was identified by the interviewed beekeepers. About 30 major honeybee floras were identified in the study area. Likewise, six poison plants for bee colony were identified by the beekeepers. An average honey yield of 7.17±6.08 in highland, 15.17±2.61 in midland and 16.62±3.056 kg/hive/year in lowland was harvested from traditional hive. Likewise, 14.73±9.14 (highland), 22.26±3.83 (midland) and 24.21±5.98 kg/hive/year (lowland) was obtained from modern hive. Honey production was significantly affected by hive types and agro-ecologies ($p<0.05$). Colony absconding was a key problem in beekeeping and more frequently and very serious absconding was observed in traditional hive with 95, 75 and 88% in highland, midland and lowland areas, respectively. About 70, 63 and 76% of the beekeepers responded the number of honeybee colony remains decreased in highland, midland and lowland areas, respectively. The major constraints affecting beekeeping development declared 14 major problems that hinder the development of beekeeping. *An average of 4.26±4.53 honeybee colonies, 70.86 kg of honey lost per household and 78293 ETB total returns lost from the sale of bee colony and honey per household due to war damage.*

Keywords: Abscond, agrochemical, bee flora, *constraints, honey, opportunities, swarming, war, trends*

CHAPTER ONE- INTRODUCTION

1. Background and Justifications

Beekeeping in Ethiopia is common and one of the agricultural activities. Traditional beekeeping was started before 5000 years back and the hieroglyphs of ancient Egypt refers to Abyssinia (the former name of Ethiopia) as the source of honey and beeswax (Mulualem and Mezgebe, 2020). Approximately 10 million honeybee colonies (95.9% traditional, 1.47% transitional, and 2.63% frame hives) are there in the country, with roughly 7 million kept in beehives by farmers and the rest living in the forests as wild colonies (Ababor and Tekle, 2018). Currently one out of ten rural households keep honeybees and the activity make a substantial contribution to rural income generation (Sahel *et al*., 2018). Because of its large number of colonies, it is Africa's biggest honey and beeswax producer. Ethiopia is fourth largest country in the world in terms of beehive population, behind India, China and Turkey. It also stands ninth in the world and first in Africa in honey production and first in Africa and second in the world in beeswax production ((Asmiro *et al*., 2017, FAO, 2020). The country has the potential to produce 500,000 tons of honey and 50,000 tons of beeswax per year (Nega and Eshete, 2018).

Ethiopia, in east Africa, with more than 10 million honeybee colonies and nearly one million beekeepers as cited by (Gebregiorgis *et al.*, 2018), has long made a beekeeping part and parcel of rural livelihood making and income generation activities. However, the way of keeping bees has been of a little value and is very traditional. The sector also supports the national economy through foreign export. Ethiopia with diversified geographical features has different climatic conditions and variable natural and cultivated vegetation which are suitable for the existence of honeybees. According to the survey report of CSA (2019) Out of the total colonies, Ethiopia owns about, 6,986,100 honeybee colony hives, of which 6,699,219 are traditional hives (95.9%), 183,924 modern hives (2.63%) and 102,957 transitional hives (1.47%). These hives provide an annual honey production of 129,301ton, of which124,791 ton (96.51%) is harvested from traditional hives, 920 ton (0.71%) from transitional hives and 3,590 ton (2.78%) from modern hives. The total bees wax production in Ethiopia was 5,521 ton in 2021 production year. This makes Ethiopia the second largest bees wax producing country in the world next to China (FA0, 2020).

In Ethiopia, despite the potential of apicultural resources, production and productivity are relatively small. This could be attributed to many factors like management, environmental factors and races of honeybees. It is known that the physical environment (altitude, vegetation, climate, etc.) greatly affects the behavioral and the productivity of honey bee colonies. Tigray region is one of the potential and well known honey producing regions in Ethiopia. It is known for its good quality white honey. Farmers in the region have long time experience of traditional beekeeping. The efforts made to improve this sub-sector from traditional practice to improved technologies is being challenged by shortage of beekeeping input materials, drought, lack of management skill and associated effects of pest and predators (Chala *et al.,* 2012; Gizachew *et al.,* 2013). In Tigray, the productivity of honeybee colonies varies from 6-25kg/hive/year using traditional hives and 16-50kg/hive/year from modern box hives *(*CSA 2013, Gebreagziabher *et al.,* 2014, Haftom and Awet, 2013). Adaptation of different honeybee races might also count on the huge variability of the productivity since previous researches identified that *Apis mellifera jementica, Apis mellifera scutellata and Apis mellifera monticola* bee races exist in Tigray regional state as cited by (Tilahun *et al.,* 2016).

Beekeeping is an important economic activity in Ahferom district. There are many rural farmers who drive their livelihood on beekeeping. The business serves as source of food, income and job creation. Despite of the fact, little is known about the honeybee production system, colony selection criteria and performance. The existing honeybee colony selection practices and colony performance behavior in different agro-ecological zones are not clearly investigated and documented. Having a clear identified honeybee colony performance helps to conserve the genetic sustainability of honeybee colonies, improve management practices and economic importance, and improves the production and productivity of honeybee colony. Moreover, the available indigenous knowledge and experience in beekeeping practice need to be explored to harness for beekeeping development. This study has generated baseline information as a prerequisite to promote beekeeping development of the study district.

2. Statement of the Problem

Beekeeping is an integral component of the agricultural activities in Ahferom district, which is blessed with high potential for beekeeping practice. Many people are based on beekeeping for their food security, income generation and livelihood. Surprisingly, there is little information on beekeeping production system, indigenous knowledge of colony selection, honeybee flora and existing constraints. However, the beekeeping production systems, honeybee colony selection and the extent of colony performance in particular for the district and in general for the region have not been investigated yet. Therefore, having well documented baseline information on these issues is a prerequisite to promote beekeeping development of the area.

This study was conducted to generate baseline information on honeybee colony selection criteria, honeybee production system and colony performance at different agro-ecologies of the study district. The farmers in Tigray region have developed their own selection criteria from their long years of beekeeping experience. The purpose of this paper was to assess the available beekeeping practice, explore the local knowledge and experience of colony selection and performance evaluation during multiplication and marketing of honeybee colonies so as to put light on possible important improvements on the sub-sector for improved benefits.

3. Objectives

3.1. General Objectives

- To assess honeybee production systems, honeybee colony selection criteria and colony performance in different agro-ecological zones of Ahferom district, Tigray, Northern Ethiopia.

3.2. Specific Objectives

- To investigate the honeybee production systems of the study area.
- To explore the indigenous knowledge and experience on honeybee colony selection criteria for colony multiplication and marketing in different agro-ecologies of the area.
- To identify and document major honeybee floras of the study area.
- To identify the major constraints of honeybee production in the study area
- To examine the impact of Tigray war on beekeeping status of the study area.

4. Research question

- What are the selection criteria of honeybee colonies in different agro-ecologies?
- Is there any difference of honeybee colony performance in different agro-ecologies?
- What are the major honeybee floras of the study areas?
- What are the major constraints of honeybee production systems of the study area?

- Does the Tigray war have impacts on beekeeping condition in the study area?

5. Hypothesis of the study

- The honeybee colonies are significantly different in their production and productivity in different agro-ecological zones.
- Honeybee floras in the study area are diverse and play a significant role in honey production.
- Honeybee production systems in the study area have been significantly affected by the Tigray War

6. Significance of the study

The purpose of this paper was to assess beekeeping production systems, explore indigenous knowledge and experience on honeybee colony selection and evaluate performance of honeybee colony so as to shed light on possible improvements on the business venture for improved benefits. The current findings could have significant benefits to different stakeholders who are involved in beekeeping development, research and marketing. Governmental and non-governmental organizations which might be interested in beekeeping activities in the study area and in other neighbouring districts can utilize the research findings. Furthermore, the findings can be used as inputs for future intervention by professionals, organizations, beekeepers, researchers and students who are interested in such studies. The generated information would help also in strengthening the local, regional, notational and global literature in apiculture.

CHAPTER TWO: LITERATURE REVIEW

2.1. The Ethiopian Honeybee Species and Races

Since the late 1700s, about 9 species of honeybees have been recognized (Roubik, 2000). These are: Apis *andreniformis, Apis cerana, Apis cerana indica, Apis dorsata, Apis dorsata binghami, Apis florea, Apis laboriosa, Apis mellifera and Apis vechti*. Among these, the following are the major honeybee species and are of world economic importance: *Apis cerana/indica, Apis dorsata, Apis florea and Apis mellifera.* Race in honeybees is a result of natural selection and honeybees have been adapted to different geographical areas of the world for many years without the interference of mankind. In so doing, there has been an environmental effect on the anatomy and physiology of honeybees leading to differentiation. The *Apis cerana* and *Apis mellifera* are managed commercially by man from the four commonly recognized species of *Apis.*

The most important and available insect in the world today is the honeybee. There are several species of honeybees existing, but *Apis mellifera* is famous in Ethiopia. It is a wonderful and popular bee type for its honey and beeswax production besides the major value obtained because of plant pollination. Different Researchers have studied the identification of honeybee races of Ethiopia. *Apis mellifera monticola* was the first honeybee race reported to exist in the Ethiopian plateau noted by smith as cited by (Teklu, 2017).

According to the report of Fkru (2015) identify the existence of five honeybee races in Ethiopia, these are, *Apis mellifera adansanii* exists in south and western part of the country, *Apis mellifera jemenitica* founds in the low land areas of eastern Ethiopia, *Apis mellifera monticola* exists in Southeast Mountain of Bale-Dinsho, *Apis mellifera litorea* exists in southwest low lands, *Apis mellifera abyssinica* exists in highland area of central, west and southern parts of the country. Ethiopian honeybees are identified into five distinct races namely, *Apis millifera jementica, A. m. scutellata, A. m. bondasii, A. m. monticola* and *A. m. woyi-gambella* as cited *by (*Godifey, 2015). African bees are much more active in collecting nectar than temperate zone bees and they are very adapted and can live in tropical climates ranging from semi desert to tropical rain forests.

2.1.1. The Morphological Variation of the Ethiopian Honeybee Races

Due to their obvious separation and clear distinctness Ethiopian bees show a considerable degree of morphological difference within the country from other honeybee populations of eastern

Africa. However, according to *(*Meixner *et al.,* 2011*)* revealed that none of their analysis provided any indication for the existence of further subdivisions inside the collection reference area.

A study conducted by (Amssalu *et al.,* 2004*) indicated that* the principal component analysis of honeybees from 285 colonies from 57 localities in Ethiopia resulted in the existence of 5 statistically separable morphometric groups. Honeybees from the eastern and north western parts of the country light in colour, relatively small and with short hairs, characteristics very related to *A. m. jemenitica* of the semi-desert parts of Sudan, Somalia and north western Ethiopia. The mean values of the morphometric characters hair length, sternite longitudinal, transverse of wax plate on sternite and wing angle fell within the range of the mean values of *A. m. jemenitica.* The shortest Mahalanobis distance was found between eastern and north western parts of the country and *A. m. jemenitica*. Honeybees occupy arid and semi-arid areas with great temperatures and low precipitation, which are ecologically similar to those of *A. m. jemenitica*. Hence, on the grounds of morphometric and ecological similarity these bees are classified as *A. m. jemenitica*.

According to (Meixner *et al.*, 2011), the pigmentation characters differed considerably and significantly between these two groups, with the Ethiopian bees being on average darker at lower altitudes. A tendency towards darker pigmentation is common in mountain insects and has mainly been discussed as an adaptation to high proportions of UV light at higher altitudes. However, several subspecies of *Apis mellifera* at low altitudes are also completely dark (e.g. *Apis mellifera intermissa)*, therefore that a strict relation between elevation and dark pigmentation does not seem to happen. The comparatively dark appearance of the Ethiopian honeybees has also been mentioned by (Tilahun *et al.*, 2016).

Amssalu *et al., (*2004*)* revealed that honeybees from the mountainous regions of northern Ethiopia were found similar to others of the east African mountains, the bees are long-haired and larger than all other southern and western, wet tropical and in the central, moist grasslands of the highlands areas of the country. The mountainous regions of northern Ethiopia bees are conversely darker than that of the east African mountains. This pigmentation variance resulted in a large Mahalanobis distance between northern Ethiopia and *A. m. monticola*. Ecologically this *A. m. monticola* occupies cool, high altitude areas (2400 m–3600 m), related to those of Kenya and Tanzania *A. m. monticolla.* Based on morphometric and ecological similarities, the northern

Ethiopia honeybee race is classified as *A. m. monticola or monticolla.* Morphometric-ally the honeybee from southern and western wet tropical areas of the country is *A. m. scutellata (*Amssalu *et al.,* 2004*).*

Honeybees happen in the central, moist grasslands of the highlands of the area the mean values of the morphometric characters of hair length, sternite longitudinal, transverse of wax plate on sternite and wing angle are nearly to those of *A. m. bandasii (*Radloff and Hepburn, 1997). Hence this honeybee found in the central, moist grassland of the highland areas is classified as *A. m. bandasii.*

Avery small honeybee colonies detected in the western and southern semi-arid to sub moist lowlands of Ethiopia, whose body size characteristics do not match any of the other African honeybees. It is distributed below the area of *A. m. scutellata* in the south west of Ethiopia. Even though these bees are slightly closer in colour to *A. m. jemenitica*, they are smaller. The shortest Mahalanobis distance was found between *A. m. woyigambella* and *A. m. jemenitica*. Then a very small honeybee colonies detected in the western and southern semi-arid to sub moist lowlands of Ethiopia, is given the name *A. m. woyigambella.*

Depending up on these different studies adaptation of different honeybee races might also count on the huge variability of the productivity since previous researches identified that *Apis mellifera jementica, Apis mellifera scutellata and Apis mellifera monticola* bee races exist in Tigray regional state (Amssalu *et. al.,* 2004*).*

2.2. Honeybee Production Systems

According to Edwards (1976), Ethiopia is endowed with an immense diversification of melliferous plants; there are over 7000 species of flowering plants existing in the country. Most of the honeybee flora comprising natural tree, forage plants, horticultural and cultivated crops (Fichtl and Admasu, 1994). These resources coupled with variable climate, edaphic factors, huge water resources and other favourable ecological factors enable the country to sustain large potentials of bee colonies. Generally, beekeeping in Ethiopia is practiced in apiary site in (backyard and forest in traditional and back yard and enclosure) areas in improved way of production system (traditional, modern, transitional and forest) (MoARD, 2007). HBRC (2004) reported that there are four different types of beekeeping practices in Ethiopia namely, traditional forest, traditional backyard, transitional and improved beekeeping.

2.2.1. Traditional Beekeeping System

According to Fichtl and Admasu (1994), a large number of honeybee colonies, estimated about 10 million are managed with the same old traditional beekeeping methods in almost all parts of the country. Traditional beekeeping has the oldest and richest practices which have been carried out by the people for thousands of years both in the forest and at the backyard. According to the survey report of CSA (2022), Ethiopia owns about 5,982,336 honeybee colony hives, of which 5,761,701 are traditional (96.31%), of beekeeping in the country is practiced in different types of traditional beehives. Over 10 types of traditional hives are reported in the country varied on the type of materials they are made from and their volume.

The report of HBRC (2004) revealed that beekeeping practices undertaken in safe guarded area for honeybees are mostly at homestead. The advantages of such practices are construction is very simple, it does not require improved beekeeping equipment and it does not also require skilled manpower. Whereas its disadvantages are inconvenience to undertake internal inspection and feeding, in same places the size is too small and causes swarming, no possibilities of supering, no partition to differentiate brood chamber and honey chamber.

2.2.2. Modern Beehive Beekeeping system

Modern beekeeping methods aim to obtain the maximum honey crop, season after season, without harming bees (Nicola, 2002). Globally, significant change in the beekeeping industry and honey yield production was realized through the application of frame beehives and certain production enhancing equipment’s. Movable frame beehives allow common bee management practices such as migratory beekeeping, supers adding or reducing, regular inspection, quality honey harvest, swarm control, feeding during dearth periods, stimulating early colony growth, and pest and disease control. These are valuable assets that enhance honey production both in quantity and quality.

According to (Gebremichael and Gebremedhin, 2014), although frame beehives were introduced to Ethiopia more than forty years ago and are known to have advantages in the production of honey, their adoption rate is very low (only about 2.7%), mainly attributing to lack or unavailability and expense of accompanying accessory equipment (mainly casting mould and honey extractor), lack of appropriate training, lack of assisting experts o technicians, *etc*. However, lately some regional states have paid significant attention to them and the recent distribution status of frame beehives is increasing.

Two types of frame hives, Zandar and Langstroth hives, are the most common that exist in Ethiopia (HBRC, 2004). The most commonly used hive type in Ethiopia is Zandar type frame beehives which have components like chamber, super (honey chamber), inner and outer cover. Frame or box beehives have advantages over the others in that it gives honey yield both in quality and quantity (HBRC, 2004).

2.2.3. Transitional Beekeeping System

It is a type of beekeeping intermediate between traditional and modern beekeeping methods. Generally, top-bar hive is a single story long box with slopping sidewalls inward toward the bottom (forming an angle of 115o with the floor) and covered with bars of fixed width, 32 mm for east African honeybees (Nicola, 2002).

Although movable frame hives are recommended for experienced beekeepers that want to optimize honey production, the Kenya top-bar (KTB) hive has been proved to be most suitable because of its low cost and the fact that the beekeepers or local carpenters can easily construct it. Transitional beekeeping started in Ethiopia since 1976 and the types of hives used are: Kenya top-bar hive, Tanzania top-bar hive and Mud- block hives. Among these, KTB is widely known and commonly used in many parts of the country (HBRC, 2004). The advantages of KTB over fixed comb hive and movable frame hive is discussed by Nicola (2002). Top-bar hive in an ideal condition can yield about 50 kg of honey per year, but under Ethiopian condition, the average amount of crude honey produced would be 7-8 kg/hive/year (Gezahegne, 2001).

2.3. Economic Importance of Honeybees

Collection and selling of honey and other bee hive products is a major economic activity (Gezahegne, 2012). It is the leading producer of honey and beeswax in Africa, with honey production estimated at 43,000 metric tons per annum. On a global scale, Ethiopia is the 4th largest producer of beeswax and the 10th largest producer of honey. Workneh and Puskur (2011) revealed that the country enabled to take the total share of honey production around 23.58% and 2.13% of the African and World's, respectively. The gross value of livestock output as sum of values obtained from estimates of off takes, milk, poultry, honey and manure give ETB birr 46,671 million, of which honey accounts 553 million birr (1.18 %) as cited by (Godifey, 2015).

2.3.1. Importance of Beekeeping for National Economy

According to MoARD (2007), apiculture is among the bubbling agricultural enterprises practiced throughout the country for its significant contribution to economic and social development at the household and national level. Apiculture alleviates poverty and improves the standard and wellbeing of the rural beekeeping community; income from the sub sector secures financial power for the purchase of necessities. Crane (1990) noted that the history of the use of beekeeping is parallel to the history of man and in virtually and every cultural evidence could be found its use as a food source and as a symbol employed in religious, magic and therapeutic ceremonies.

According to Gezahegne (2012) and SNV Ethiopia (2012), the sub sector is one of the few sectors that had the most inclusive ability to achieve transformation and growth across all categories of rural households. In Ethiopia, more than 5 million beehives are managed approximately 1.4-1.7 million farm households, who are keeping bees as a means of additional income generation.

2.4. Behavioral Characters of Honeybee Colony Selection Criteria

According to Tilahun *et al.,* (2016), beekeepers experience on characterizing black, red and mixed coloured bees in the three agro-ecological zones evaluated the three categories of colonies with respect to honey yield, dry season brooding ability, aggressiveness, absconding behaviour and swarming tendency. The black coloured bees stood first in honey production according to the interviewed beekeepers in Kolla and Weinadega agro-ecological zones. The black coloured bees were also ranked the highest in swarming tendency in all the agro-ecological zones. Beekeepers explained that the black coloured bees were easier for multiplication by splitting due to their high swarming tendency. Black coloured bees were considered to be the best honey yielding with high brooding ability during the dry season which made them resistant to drought. Black coloured colonies were also reported to be resistant to enemy attacks that cause the bees to abscond. It was only in Dega agro ecologies that the red coloured bees were preferred to black and mixed colours for honey production.

2.5. Colony Performance and Selection Criteria of Honeybee Colony

The performance evaluation of honey bee colonies among different races and ecotypes is very critical to place foundation for future selection and improvement of the best productive races. Selection of honeybee colonies adapted to local conditions is therefore an important step to be successful in the beekeeping sector. Farmers in Tigray region of Ethiopia have developed their own selection criteria from their long years of beekeeping experience. Worldwide experiences showed that selection of honeybee colonies could be made on the basis of disease resistance, drought tolerance, hygienic behavior, aggressiveness or defensive behavior and tendency of swarming and absconding, foraging behavior, propolis collection, pollen, nectar and honey yield storing activities.

Selection of honeybee colony plays an important role for successful harvesting of desired products from honeybees. The purpose of this study was therefore to assess local knowledge and experience of beekeepers in Tigray regional state of Ethiopia with regard to colony selection and management practices during purchase and multiplication based on the existing conventional agro ecological zones namely Dega (highland), Kolla (lowland) and Weinadega (midland).

The findings of Tilahun *et al.,* (2016) indicated that beekeepers were using six local selection criteria namely worker bee population, body colour, comb building direction, aggressiveness, honey yield history and age of the colony ordered according to their preference rank from 1 to 6. Beekeepers understood that selection of honeybee colonies was important because productivity, management easiness and agro climatic adaptation of colonies are different for different colonies. As a result, colonies with dominant black coloured bees were chosen as first priority for their merits of better honey productivity, tolerance to absconding and multiplication easiness in Weinadega and Kolla agro ecologies. However, red/yellowish coloured bees were preferred in Dega agro ecology.

2.5.1. The Performance of Honeybee Colonies on Honey Yield

A study by Tesfa and Kasa (2019) showed that the honey production and productivity depend on various factors and prevailing conditions of the area. The factors that affect honey yield production could be considered as types of the honey bee races, agro-ecology, weather conditions, availability of food pollen, nectar and resins and health status of the colonies and strength of the colonies. The honey yield result shows none significant difference per year per hive of the tested colonies. The mean honey yield (kg) per harvest per hive 15, 10.67 and 14.33 in 2016, 2017 and 2018 years, respectively.

When compared to the average national yield (19.8 kg) of colonies in frame hives from *A.m.bandansii* colonies produced significantly less honey yield production. The findings of A. m. bandansii at Jimma zone was higher than the honey yield results per harvest per hive of the A. m. scutellata honeybees' colonies with 9.64 and 11.54 for the year 2011 and 2012, respectively. An average honey yield of 12.47 and 12.07 kg/year on 2006 and 2007, respectively were reported by (Olszewski and Paleolog, 2016) for *A. m. bandasii* at Gedo sub site of HBRC.

The productivity of honeybee colonies in Tigray region was reported to varies from 6-25kg/hive/year using traditional hives (CSA, 2013) and 16-50 kg/hive/year from modern box hives (CSA, 2013; Haftom and Awet, 2013; Gebreagziabher *et al.,* 2014). This huge variation might be as the result of variations in availability of bee flora, differences in management practice of farmers, exposure of apiary sites to different pests and climatic fluctuations over seasons and years.

2.5.2. Comb Building Direction of Honeybees

According to Tilahun *et al.,* (2016), beekeepers recognized that honeybee colonies in Tigray region construct their combs in three directions (Dfo, Goni/Seyaf and Sala). Sala is the one where combs are built parallel to the length of the traditional hive and Dfo is perpendicular to the long side of the hive. Goni or Seyaf are built neither perpendicular nor parallel to the length but slanting along the length by some angles to the width. These characteristics were less frequently seen in European box hive where colonies are guided to construct combs along the frames on the foundation sheet. In traditional hives, farmers prefer honeybee colonies that construct their comb in parallel pattern to the length side, as this facilitates harvesting. Identification of the ripe honey combs and occasional inspection is easier if bees construct their comb in parallel pattern along the length side of the hive.

2.5.3. Swarming Tendency of Honeybee Colonies

According to Melkam *et al.*, (2017*)*, in line to most findings in *A.M Weyi gambella* race, the mean construct 4.66±4.72 queen cells in January which was maximum number of queen cells observed month in most colonies and not at all in some colonies, like March and June. Whereas others produce queen cell in November, December, February, March, April, May and June 2.00±0.00, 3.00±2.82, 1.50±0.70, 1.50±0.70, 1.50±1.00, 2.66±2.88 and 1.5±1.00, respectively. The honeybee colonies swarming tendency evaluated by counting the number of constructed queen cells from all colonies and the produced number of swarms during the normal honeybees' reproduction season. (Tesfa and Kasa, 2019) reported that the swarming tendency indicates high swarming tendency observed in October and November than any other seasons.

2.5.4. Absconding Tendency of Honeybee Colonies

The absconding of honeybee colonies refers to the release of colony to leave the nest and searching to another. A study by Melkam *et al.*, (2017) revealed that in *A.M Weyi gambella* around 26% of the total colony leaves their nest at the period of pollen and nectar shortage mostly at the end of May to July. Most of the absconding occurred during summer and rainy dearth in May and July due to short supply of nectar and pollen, unfavorable climatic conditions and parasitic and predatory pressures. As a result, there is not insured remaining honey, nectar or pollen comb except some brood one in the hive. Tesfa and Kasa (2019) remarked that the absconding of colony very serious among the confirmed colonies due to frequent disturbances, pest attacks, shortage of bee forage in the rainy season which might be due to dearth or pesticide application used for crop production in the area. At the time of pollen and nectar shortage mainly July to August the absconding observed on an average 20.3% over the last three years and during colony transfer from traditional hive high absconding of colonies observed which might be due to lack of internal feeding and not using queen cage.

2.6. The Major Constraints of Honeybee Production System

The prevailing production constraints in the beekeeping development of the country are complex and to a large extent vary between agro-ecological zones and production systems (EARO, 2000). The shortage of bee forage, pesticide poisoning, lack of skill and knowledge, low level of technology and honey bee disease, pests and predators are the top five major constraints in most part of the country (Workneh and Puskur,2011; Gidey *et al.*, 2012).

The major challenges of the beekeeping in the study area were shortage of bee forage especially during dry periods followed by absconding, pests and predators, unwise application of agrochemicals as stated by (Alemayoh *et al.,* 2021) in Arba Minch Zuria District, Southern Ethiopia. The major beekeeping constraints are technical and institutional which come from honeybee's characteristics or environmental factors that are beyond the control of the beekeepers, whereas others have arisen with poor marketing infrastructure and storage facilities. Based on the information of the sample respondents, there were a number of difficulties and challenges that are hostile to achieve the success of desired honey production. The identified and prioritized major problems facing the beekeeping activities Shortages of bee forages, Pests and predators, lack of beekeeping equipment's, Application of herbicides and pesticides, Lack of improved bee hive, Absconding Migration, Lack of extension services, Swarming and Drought (Tizazu, 2018) in Sayo district western Oromia Ethiopia.

2.6.1. Honeybee Colony Diseases, Pests and predators

Like all living animals, honey bees are infected with disease and attacked by parasites and pests endangering their health and life (AlGhzawi *et al.,* 2009*).* These diseases of honey bees impose serious problem on honey bee production and productivity. Major constraints of honeybee production are frequent occurrence of drought, lack of bee forage, existence of pests and predators and pesticide poisoning in decreasing order of importance (Adeday *et al.,* 2012*).* The major pests and predators are indicated as honey badgers, ant like insects, wax moth, birds, spiders, monkeys, snakes and lizards by (Adeday *et al.,* 2012*).*

According to the report of (Bekele *et al*., 2017) the existence of pests and predators were a major challenge to the honeybees and beekeepers and in Bale zone south eastern Ethiopia, the most harmful pests and predators Honey badger (*M. capensis*), spider *(Latrodectus mactan),* bee-eater birds, bee lice (*Braula coeca),* beetles (*Aethina tumida*), wax moth *(Galleria mellonella),* wasps *(Polistes fuscatus),* death head hawk moth *(Acherontia atropos)*/(*Irbaataibiddaa in afanoromo*), mice, lizards, snake, pray mantis, and monkey were the most dangerous pests and predators in order of importance. Other findings reported in Ethiopia (Belie, 2009; Chala et al., 2012; Shunkute et al., 2012). Honey badger attacked a serious problem and stand out in the area causing disappearance of honeybee colonies.

2.7. Bee Forage and Its Role for Honeybees

Beekeeping is a keeping of honey bee with a very long history and deep rooted household activity in Ethiopia. Owing to its varied ecological and climatic conditions, Ethiopia is the home of diverse flora and fauna in Africa (Sahle, Enbiyale *et al*. 2018). Due to its wide climatic and edaphic variability, Ethiopia is endowed with diverse and unique flowering plants of 6000 to 7000 species and over 800 are identified honey bee forages, thus making it ideal for beekeeping (Teklay 2011, Tulu, Aleme *et al*. 2023). Plants are the food source of honeybees. However, Yetmwerk et al., (2015) revealed that all plants are not important for honeybee some plants are poisonous. Honey bee plants are best suited for honey production as well as colony maintenance by obtaining protein from pollen source plants and carbohydrate from nectar source plants (Bista and shivakoti, 2001). Honeybees with their activity of extending their proboscis into the flowers are considered as nectar source and bees carrying pollen on their hind legs were determined as pollen source (Mbah and Amao, 2009). Generally, assessing the potential bee flora and their importance as a major or minor for honeybee plant is very important in bee forage management (Mbah and Amao, 2009). Because of the availability of diversified plant species, climatic condition, topography and rain fall distribution Tigray region has large number of honeybee colonies Alemtsehay (2011) and those plants that supply both nectar and pollen abundantly when in bloom and these are often called honeybee plants. However, honey production in Tigray is basically seasonal with excess production at certain time of the year.

The report suggested that honey bee floras such as, *Eucalyptus globulus, Becium grandiflorum*, and *Leucas abyssinica* are believed to affect color and test of honey. Thus, special white honey believed to be produced from *Leucas abyssinica* which is highly demanded honey in Tigray region. But this needs to considered pollen analytical study to verify it confidentially. Honey harvesting is more or less seasonal, which depends on the flowering calendar and a large amount of honey was harvested in September and October followed by November to December of the year by Kiros and Tsegay (2017) in Eastern zone of Tigray, Ethiopia.

CHAPTER THREE: MATERIALS AND METHODS

3.1. Descriptions of the Study Area

3.1.1. Location

The study was conducted in Ahferom district, central zone of Tigray regional state, Northern Ethiopia. Enticho is the administrative town of the district. Ahferom district is bordered on the south by Werei-Leke district, on the west by Adwa, on the north by Eritrea and on the east by Ganta-Afeshum and Gulomekeda districts. The district is located at $14^{o}08'43''$ to $14^{o}11'47''$ North latitude and $38^{o}53'55''$ to $38^{o}57'30''$ East longitudes. The study Woreda were selected due to its high colony population, indigenous beekeeping experience, extent of beekeeping activities, beekeeping potential, and it has representative agro ecology (highland, midland and lowland) areas in the mountainous landscapes of Tigray region, northern Ethiopia.

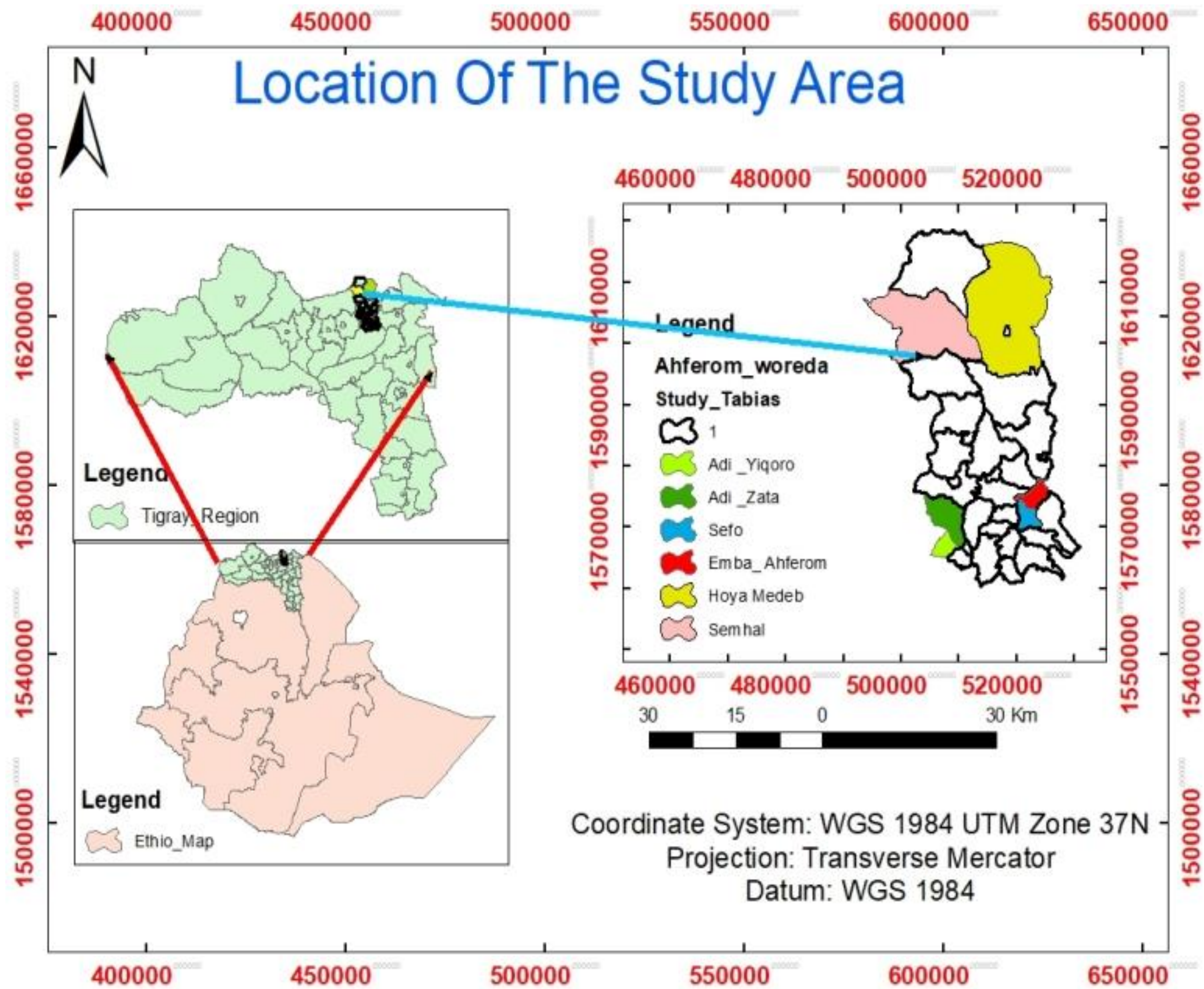

Figure 1: Location map of the study area

3.1.2. Vegetation

Vegetation cover of the study area is mixed of scattered acacia trees, riverine forests and bush scrub. Consists of natural forest, bush land, shrub land and mixed or enrichment secondary forest. The study area is located in the most degraded part of the region and almost devoid of vegetation coverage or biomass for decades. Dispersed trees, and shrubs in ex-closures, trees, and Acacia species are the dominant woody species found in the study Woreda. The dominant naturally regeneration trees and shrubs species of the sites are Acacia lahay, Acacia etbaica, Acacia senegal, Acacia seyal, Carissa edulis, Euclea schimper, Acacia aska Mytenus senegalensis, Rhus natalensis, Euphorbia abyssinica, Cupparis micrautha and Dodonea angustifolia (source: AO and NRM sector, 2018)

3.1.3. Land Use and Demographic Features

The total area of the Ahferom district is about 133,979 hectares, of which about 23,434 ha is cultivated (17.49%), 21,458 ha forest covered (16.02%), 18,823 ha bare land (14.05%), 17,389 ha grass land (12.98%), 1,374 ha unused land due to Ethio-Eritrea conflict (5.86%) and 51,501 hectares are miscellaneous (38.44%), and 2400 ha is suitable for irrigation from the cultivated land. Ahferom district has a total human population of 206,993 and 46,395 households. From the total population, 48% (99,357) and 52% (107,836) are males and females, respectively. The numbers of households living in the rural Tabias of the district areas are 36,524 (23,923 male households and 12,601 female households). The livelihood of the population living in the district is directly or indirectly depends on agricultural activities (AWOARD, 2018). The study district owns large livestock population with 162,004 cattle, 174,440 goats, 59,669 sheep, 24,128 equines, and 34,465 honeybee colonies.

3.1.4. Farming Systems

Agriculture is the main stay of smallholder farmers of the district. The district has agricultural potential, which is reflected in the diversity of crops and animal resources. The major types of animals rearing in the study area are cattle, sheep, goats, equines, poultry and honeybee colonies. In general, the main economic activities of the study area are mixed crop-livestock farming, which being practiced by the smallholder farmers (LIVES, 2012).

3.1.5. Topography and Climatic Conditions

The district receives an annual rainfall ranging from 550 to 850 mm and the annual mean temperature ranges 22 to 27^{o}C. The altitude ranges between 1453 and 2990 masl.

The environment is heterogeneous in terms of topography, climate and land use cover. The district comprises 33 Tabias, of which 6 are urban Tabias and 27 are rural Tabias. The agro-ecological zones of the district are lowland (*Kola*), midland (*Weyna-dega*) and highland (*Dega*). From the 27 Tabias, 4, 17 and 6 Tabias belong to lowland, midland and highland, respectively, (AWOARD, 2018).

3.1.6. Geology and Soil

Ahferom district is mostly covered by silt clay loam soils. The topography of the area is almost highland featured, midlands and few flat lands with some rocky areas which are called the Enticho sandy stones (AWOARD, 2018).

3.2. Sample Size and Sampling Methods

A multistage sampling technique was applied for this study. At the first stage, the study district was selected purposively based on its potentiality in beekeeping. In the second stage, the district was stratified into three strata based on agro-ecology. In the third stage, six Tabias (two from each stratum) were selected deliberately considering the beekeeping potential. In the fourth stage, representative beekeeper samples were selected using simple random sampling method. In the fifth stage, beekeepers with a minimum of five years experiences that have three or more honeybee colonies were included in the sampling frame. The numbers of beekeeper respondents were selected based on the population of the beekeepers in the district area and the same in each stratus and Tabia that can represent the data collected. A total of 180 beekeepers (60 from each agro-ecology) were chosen randomly. 30 participants per Tabia and 180 participants in the district should lead to maintain and achieve 80% power (the minimum suggested power for an ordinary study) (Cohen, 1988) to detect the differences and relationships of the participants.

3.3. Data Collection Methods

3.3.1. Questionnaire Survey

A semi-structured questionnaire was developed in English and it was converted to the local language Tigrigna. The questionnaire was made to include questions related to household characteristics (age, sex, education, family size, marital status, land size, and livestock holding), number of honeybee colony, beekeeping practices, honeybee colony selection criteria, honeybee colony performance, honeybee flora, available constraints, and other relevant information. The questionnaire was refined using a pre-test survey, and interviews were conducted with the selected beekeepers using the questionnaires. Six separate focus group discussions (one from each Tabia) were held with representative groups. In addition to this, interviews were held with key informants and beekeeper experts. The number of participants in the FGD (male-7 and female-3) in each group with a total number 60 participants and key informants (male-15 female-5) were interviewed. Observations and pictures were employed to collect additional data and information. The honeybee constraints and identification of honeybee floras were assessed from the respondent interviewee by a questionnaire survey and personal observation. Enumerators were recruited and trained how to collect data and survey.

3.4. Data Analysis Procedures

Analysis of variance (ANOVA) procedures were employed to analyse the quantitative data and the qualitative data also analysed using the qualitative descriptions (non-parametric methods) from the data generated in survey method. The collected data were coded, managed and tabulated for analysis. A General Linear Model (GLM) procedure of *SPSS software version 23* was used for data analysis. Simple descriptive statistics such as mean, standard deviation, frequency and percentage were used to summarize results. Post hoc Tukey HSD was used to separate mean differences to declare the significance at $p<0.05$. The relationships between variables were seen using a correlation coefficient. The statistical model for the analysis of the data was.

$Y_i = \mu + A_i + e_i$ Where: Y_i = Response variable (dependent variable)

μ = Overall mean

A_i = Effect of agro-ecology

e_i = Error term (residual error)

$$\text{Index} = \frac{Rn * C1 + Rn - 1 * C2 \ldots +R1 * Cn}{\Sigma(Rn * C1 + Rn - 1 * C2 \ldots .+R1 * Cn)} \text{---} 1$$

Where,

Rn = Value given for least ranked level (if the least rank is 11^{th}, then Rn=11, Rn-1=10, R1 = 1)

Cn = Counts of the least ranked level (in the above example, the count of the 11^{th} rank =Cn, and the count of the 1^{st} rank = C1)

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Demographic and Socio-Economic Characteristics of the Respondents

4.1.1. Gender of the Respondents

From the total of 180 sample households interviewed, about 88% were male headed and the rest 12% were female headed. This result is similar with Godifey (2015) who reported that from the total of 384 sample households interviewed, about 91.1% were male headed and the rest 8.9 % were female headed in selected zones of Tigray region, Northern Ethiopia. However, the study result indicated that the participation of women in beekeeping is better than the finding of Belie (2009) who report about 98.3% were male headed and the rest 1.7% were female headed in Burie district of Amhara region, Ethiopia.

Out of the total respondents, about 80%, 93% and 90% in highland, midland and lowland areas were males, whereas 20%, 7% and 10% were females, respectively (Table 1). Women participation in beekeeping activities was higher in highland than lowland and midland areas. This indicates that the participation of women in beekeeping activities in the study area is much lower than male. This might be due to the fact that even though women are able to work, beekeeping is considered as the work of men. The women's share of beekeeping work (cleaning under the hive house, protect from birds and different pests and predators) often exceeds that of men. This may be due to the reduced involvement of the government and non-government in supporting wisely female household headed farmers through beekeeping activity. Consequently, in order to increase the women's motivation in honey production, it is important to focus on women training.

This result is in good agreement with the result of Haftu et al., (2015) who stated that most of the interviewee household heads were male (89%) and the rest were female headed households (11%) in selected areas of Hadya zone, Ethiopia. Based on the group discussion made with beekeepers, the less participation of women in beekeeping could be due to fear of honey bees sting and not have enough time to be involved in beekeeping due to their responsibility to do much of the household activities.

4.1.2. Marital Status of the Respondents

Marital status of the sample respondents indicated that about 77%, 90% and 80% in highland, midland and lowland were married, respectively. Whereas, 20%, 8% and 10% in highland, midland and lowland were divorced, while 2%, 2% and 7% were widowed, respectively (Table 1). Of the total sampled respondent beekeepers, 82% were married.

Table 1: A summary of gender, marital status, and age of respondents

Variables	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Gender								
Male	48	80	56	93	54	90	158	88
Female	12	20	4	7	6	10	22	12
Marital status								
Single	0	0	0	0	0	0	0	0
Married	46	76	54	90	48	80	148	82
Divorced	12	20	5	8	6	10	23	13
Widow (female)	1	2	1	2	4	7	6	3
Widower (male)	1	2	0	0	2	4	3	2
Age range of HH (years)								
18-30	0	0	0	0	0	0	0	0
31-45	20	33	18	30	14	23	52	29
46-65	32	53	31	52	27	45	90	50
66-75	4	7	11	18	16	27	31	17
Above 75	4	7	0	0	3	5	7	4

HH = Household, N= Number of observations

The result indicated that beekeeping activities could be performed by every group of the community regardless of their marital status. The beekeepers responded that even though beekeeping could be performed by every group, the work of keeping bees and control the enemies of the honey bee individually are difficult. Therefore, the participation of unmarried (single) beekeeper is very small in the study area. This result is related with the study of Haftu and Gezu (2014) who indicated that of the total households interviewed, 97% were married Hadya Zone, Ethiopia. The authors added that married households have always a chance to get training and other advantages than other peoples.

4.1.3. Age of the Respondent Beekeepers

Of the sampled households, about 27%, 30% and 23% in highland, midland and lowland were under the age range of 31 to 45, respectively, whereas 67%, 52% and 45% were in the age range from 46 to 65 and 7%, 18% and 27% in the range of 66 to 75, respectively. The proportion of households age ranges above 75 years were 7% in highland and 5% lowland (Table 1).

At district level, about half of the respondent households (50%) had age of 46-65 years, while 29% were aged 31-45 years. This indicates that most of the beekeepers were adult who are in active age for labour force. This result is similar with *(*Godifey, 2015, Haftu and Gezu, 2014) who reported that the average age of the respondents was 40 to 55 years in Tigray, region and in Hadya zone of southern Ethiopia. In the current study, the survey result showed that beekeepers in the most productive age were actively engaged in beekeeping activities. This indicates that the advantage of beekeeping is known as other agricultural activities such as crop cultivation and livestock husbandry. With regard to religion, all the sampled beekeepers (100%) in all agro-ecologies were Orthodox.

4.1.4. Educational Background of the Respondents

In terms of educational background, about 10%, 17% and 42% of the beekeepers in the highland, midland, and lowland, respectively were illiterate, while 12% in midland and lowland beekeepers can read and write. About 17%, 22% and 27% in highland, midland and lowland areas beekeepers were primary school educated (1-4 grade), while 55%, 35% and 15% of them were junior school educated (5-8 grade), respectively. About 17%, 15% and 5% of the beekeepers in the highland, midland, and lowland attended secondary education (9-12 grade), respectively, whereas the remaining 2% were college graduates (Table 2).

Table 2: Proportion of educational status of the respondents of the study area

Educational level	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Illiterate	6	10	10	17	25	42	41	23
Can read and write	0	0	7	12	7	12	14	8
Primary education (1-4)	10	17	13	22	16	27	39	22
Junior education (5-8)	33	55	21	35	9	15	63	35
Secondary education (9-12)	7	17	9	15	3	5	22	12
College	1	2	0	0	0	0	1	0.5
Total	60	100	60	100	60	100	180	100

HH = Household, N= Number of observations (N = 180)

In general, majority of the beekeepers (77%) were educated, while 23% were illiterate in the study area. The FGD participants also mentioned that illiterate beekeepers have low participation on improved beekeeping as working with frame hive need specific technologies. The beekeeper must write and read what so that to be trained by experts. This result was in good agreement with that of Godifay *(*2015*)* who reported that most keepers (78%) were educated, while some (22%) were illiterate in selected zones of Tigray region, northern Ethiopia.

The current result reveals that beekeeping was practiced by both groups (literate and illiterate). However, the FGD participants mentioned that beekeepers with better educational background are more productive. Therefore, education is an important factor which if lacking can negatively impact on future improved beekeeping and adopting new technologies.

4.1.5. Experience of Beekeepers

The overall mean value of the beekeepers' experience in the different agro-ecological zones was 18.71±9.43 years with the range of 5 to 56 years. The mean value of the beekeeping experience was 20.22±9.77 years in highland, 20.18±10.51 years in midland and 15.73±7.09 years in lowland (Table 3).

Table 3: Experience, land and livestock holding of beekeepers of the study area

Variables		Agro-ecology				
		Highland	Midland	Lowland	Overall	P-value
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	
Experience		20.2±9.78	20.18±10.5	15.7±7.1	18.7±9.43	0.011
Average land holding		0.29±0.2	0.31±0.3	1.15±0.56	0.59±0.57	0.000
Land holding	Yes (%)	75	62	92	76	-
	No (%)	25	38	8	24	-
Livestock holding	Yes (%)	80	95	100	90	-
	No (%)	20	5	0	10	-

N= Number of observations (N = 180), SD = Standard deviation

The survey result showed that there was significant difference in beekeepers experience between highland and midland agro-ecologies ($p<0.05$), while there was no significant difference between lowland and the two ecologies ($p>0.05$). This implies that people are actively engaged in beekeeping from an early age. Most of the respondents have confirmed that their children even at early ages are also engaged in beekeeping in helping parents. Based on this exposure, young people gradually move on to become independent beekeepers as soon as they obtain their own colonies especially in highland areas and accumulating experience by seeking technical information from corresponding beekeepers whenever required especially in highland areas.

The result showed that beekeeping practice in highland and midland areas appeared to be a long time activity as compared to lowland areas. This result is in opposite with the findings of Tilahun *et al*. (2016) who found that beekeeping practice in lowlands (*Kolla*) appeared to be a recent activity compared with highlands (*Dega*) and midlands (*Weinadega*) in Tigray, Northern Ethiopia.

4.1.6. Land Holding of the Respondent Households

The average land holding of the sampled respondents was 0.29±0.2, 0.31±0.3 and 1.15±0.59 hectare in the highland, midland and lowland, respectively and a maximum land holding of 0.5, 0.75 and 2.25 hectare in the highland, midland and lowland, respectively (Figure 2). The overall mean of the land holding of the household respondents was 0.584±0.556 hectares (Table 3). The current land size is below the national average household land holding (1-1.5 ha) (CSA, 2017). Godifay (2015) also found about 0.6±0.4 hectares land size per household in selected zones of Tigray region, northern Ethiopia.

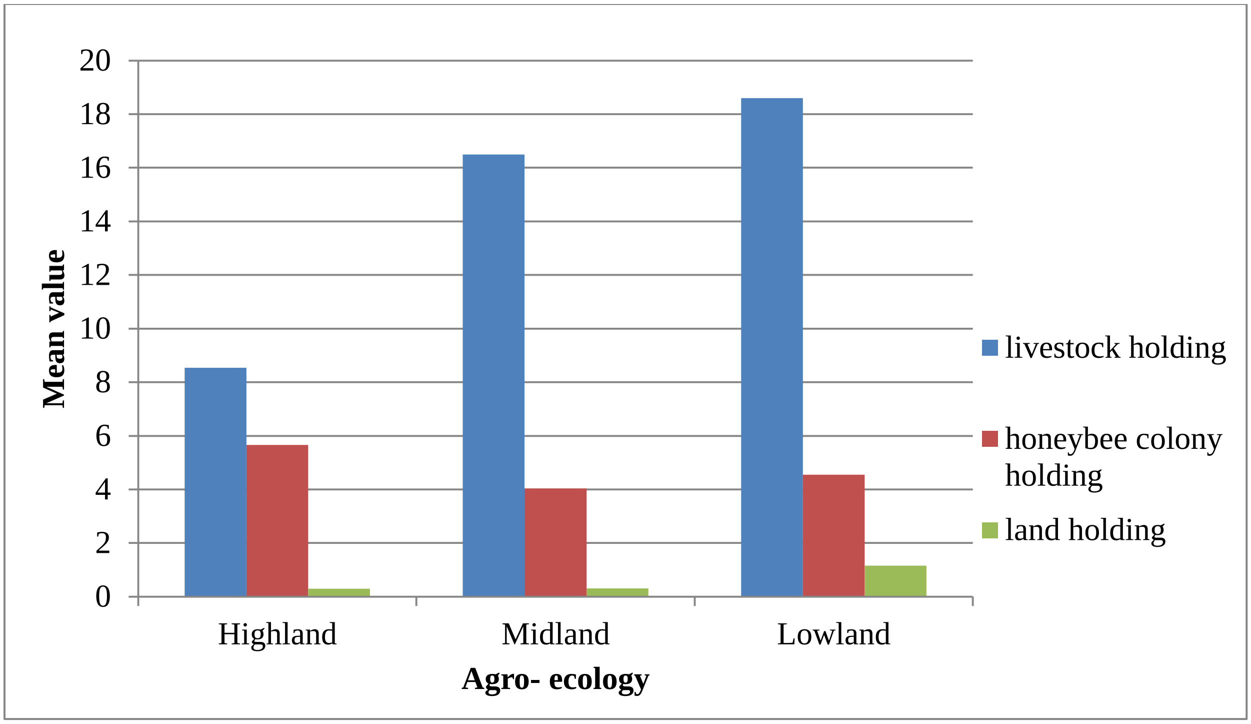

Figure 2: Average livestock, land and bee colony holding by the respondents in the study area

About 25%, 38% and 8% of the beekeepers had no land in highland, midland and lowland, respectively and it was 24% for the overall (district). The current result indicates that beekeeping activity of landless beekeepers' participation in midland (38%) was higher than in highland and lowland areas and higher in highland than lowland areas, which indicates beekeeping can be applied and performed even with those who have no land holding youth (Table 3).

4.1.7. Livestock Holdings and their Purposes

The respondent explained that the farming system of the area is as an integral part of the mixed farming system in which livestock production plays a substantial role in the household food security. It also meets urgent financial need, dietary requirements, draught power, transport, loan repayment, dowry and gift, fuel, fertilizer, as a buffer in the case of crop failure, and also for social and cultural functions. As shown in the table, the major livestock types reared in the district include goats, poultry, sheep and cattle. About 80%, 95% and 100% of the beekeepers had livestock in highland, midland and lowland, respectively, while 20% and 5% in highland and midland had no other livestock, respectively.

The average livestock holding size was 3.28 TLU per household. The TLU value was higher for lowlands (3.97) as compared to midlands (2.84) and highlands (1.77) per household ($p<0.05$) (Table 6). The mean livestock holding per household was observed to be 2.36 heads of cattle, 2.21 sheep, 4.03 goats, 4.91 chickens, 0.92 donkeys and 0.1 camels (Table 4). The most important resources owned by sampled households were poultry, goat, sheep and cattle, respectively. In general, among the interviewed households, 10% owned with no livestock, indicating that resource poor farmers are also participating in beekeeping.

Table 4: Types of livestock and livestock ownership of the beekeeper households

Animal type	Agro-ecology								
	Highland		Midland		Lowland		Overall		p-value
	Head	TLU	Head	TLU	Head	TLU	Head	TLU	
Cattle	1.58±1.1	1.11	2.15±1.2	1.51	3.35±1.4	2.35	2.36±1.4	1.65	0.000
Sheep	1.45±2.6	0.15	2.13±3.4	0.21	3.04±4.4	0.30	3.04±4.4	0.30	0.000
Goat	1.85±2.1	0.15	4.62±4.9	0.37	5.62±5.6	0.45	5.62±5.6	0.45	0.000
Poultry	3.03±3.3	0.04	6.38±6.6	0.08	5.32±5.9	0.07	5.82±5.9	0.08	0.000
Donkey	0.63±0.6	0.32	1.13±0.7	0.57	1.02±0.7	0.51	1.02±0.7	0.51	0.000
Camel	0.0±0.00	0.00	0.08±0.3	0.10	0.23±0.5	0.29	0.23±0.5	0.29	0.000
Total	8.54±9.7	1.77	16.5±17	2.84	18.6±18.5	3.97	18.1±18.5	3.28	-

TLU = Tropical livestock unit, TLU of each livestock species; cattle = 0.70, sheep = 0.10, Goat = 0.08, Poultry = 0.013, donkey = 0.50, Camel = 1.25, N = Number of observations (N = 180)

4.2. Beekeeping Production Systems and Trends

4.2.1. Beekeeping Practices in the Study Areas

There are two types of beekeeping production systems in the study district. The beekeeping production system is classified as traditional and modern based on the types of beehives used. The number of traditional and improved frame beehives owned per household varied among different agro-ecology and beekeepers. The same finding was reported by Alemayehu *et al*. (2021) in Arba Minch Zuria district, Southern Ethiopia in which based on the input used and their management practices, two types of beekeeping practices were mainly used for honey production. These are local (traditional) and modern (frame) beehive beekeeping. The traditional beekeeping was practiced as traditional backyard beekeeping around homestead with relatively better management provided to bee colonies. The modern frame hives are placed in apiary sites and the adoption rate of modern hive is very low as per the author (Alemayehu *et al*., 2021) in Arba Minch Zuria district, Southern Ethiopia. Beekeeping is an old practice in Ahferom district and it is an ancient farming activity which is practiced as a side line business with other farm activities but as a main income source.

4.2.1.1. Traditional Beekeeping System

The present study showed that traditional beehive types are either made locally by the beekeeper family or partners in the house in which the hives are made up by locally available materials like mud and cow dung. Many of the traditional hives were not in appropriate size and shape for bees to maintain them but all were oval in shape with unknown dimension in length and diameter. Most of them were either larger or smaller than required. As per the information gathered from the respondents and discussants, they plaster interior of hive by mud and cow dung to protect bees from cold and warm weather conditions and external part are covered with grass especially in highland areas to protect from rain and sun.

According to the survey result, the mean bee colony owning of traditional hive was 5.38, 2.93 and 4.03 in highland, midland and lowland areas, respectively. The honeybee holding of the respondent beekeepers in highland was significantly ($p<0.001$) higher than that of midland and lowland areas and also significantly higher in lowland) than midland areas ($p<0.001$). The overall mean of colony holding in traditional hive was 4.12 with a maximum of 12 per household. These results are lower when compared with that of Belie (2009*)* who reported mean honeybees colony holding in traditional hive to be 7.75 per household in Burie District of Amhara Region, Ethiopia. As expected, it was observed that the number of traditional hives (4.12) was higher than modern hives (0.64) (Figure 3). Surprisingly, the beekeepers prefer traditional hives even though higher quantity and quality of honey yield is found from modern frames. This could be related due to the reason to avoid absconding tendency, cost and availability.

Similar observation was reported by Nebiyu and Messele (2013) who found that most of the beekeepers (74.4%) preferred traditional hives over the modern hives (14.1%) in Gamo Gofa zone of southern Ethiopia. This is mainly because of the cost of constructing and purchasing of modern hive and lack of harvesting and processing equipment to use modern and improved hives. Similarly, Mahari (2007*)* reported that modern beekeeping productions require more expensive establishment cost, accessories and skill training although better quality and quantity of honey is harvested in Atsbi Wemberta and Kilte Awlailo Woredas of Eastern Tigray, Ethiopia.

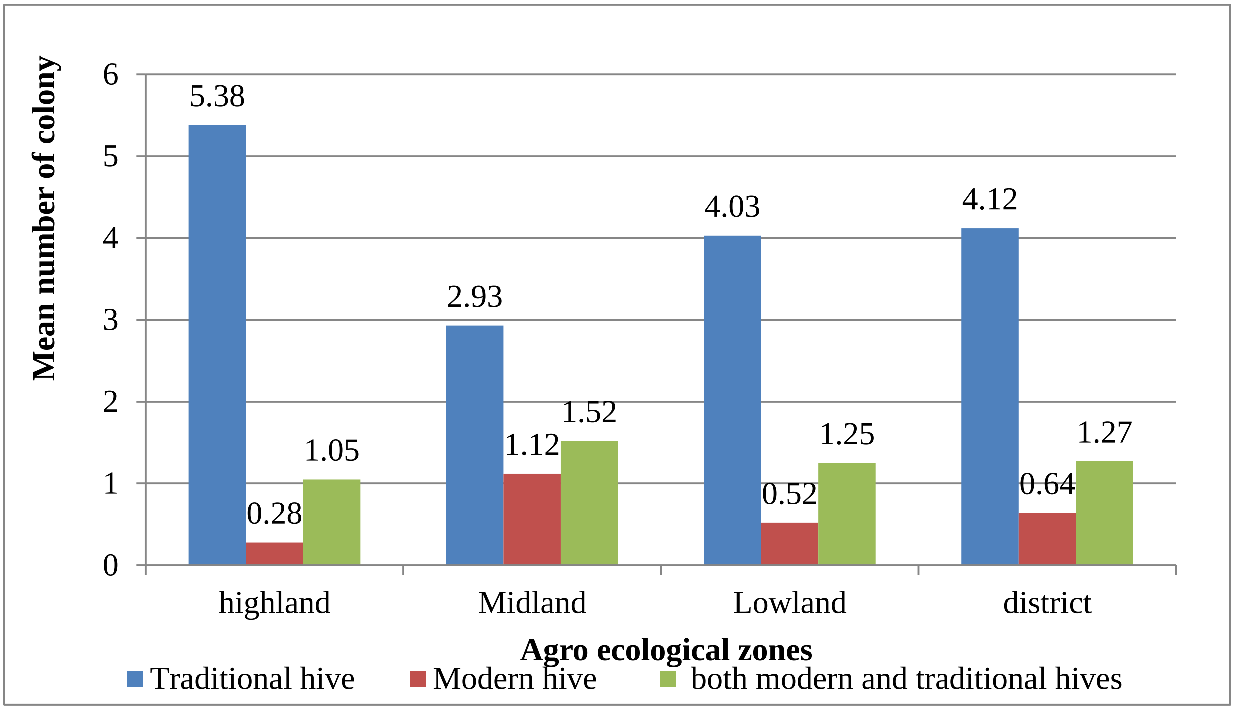

Figure 3: Honeybee colony holding in traditional and modern beehive in the study area

4.2.1.2. Modern Beekeeping System

The quantity and quality of hive products production primary depend on the type of beehive used. According to the result of this study, the use of movable-frame hive was very low as compared to traditional beehive with overall mean holdings of 0.64 and maximum of 10 modern hives per households ($p<0.05$). Accordingly, the sampled beekeepers owned an average of 0.28, 1.12 and 0.52 modern frame hives in highland, midland and lowland areas, respectively. The number of modern hive holding was significantly higher in midland than highland and lowland ($p<0.05$) areas and higher in lowland than in highland areas ($p<0.05$). The result indicates that the beekeepers own very small number of modern hives in the district and this is probably because of poor extension services simply they introduce modern hive to the area without enough theoretical training with practical training, awareness and low intervention on beekeeping development by the government. Currently, the costs of movable frame hive ranges from 6500 to 7000 Ethiopian birr which is not affordable by the poor smallholder farmers as per the information gathered from Ahferom office of agriculture and rural development.

The current finding agreed with that of Alemayehu (2021) who observed that the adoption of modern hive was low in Arba Minch Zuria district, southern Ethiopia. The author stated that the adoption rate of modern hive was very low due to shortage in supply of beehive accessories, lack of knowledge on how to operate the box hive, weak beekeeping extension services and lack of intervention on beekeeping by government and non-governmental organizations. According to Crane (1990), movable-frame hives allow appropriate colony management and use of a higher-level technology with larger colonies, and can give higher yield and quality honey but, are likely to require high investment cost and trained man power as compared with traditional hive.

Figure 4: Modern hive production system

4.2.3. Honeybee Colony Holding and Hive Types

The number of traditional and improved frame beehives owned per household in the survey time varies among agro-ecologies and beekeepers (Table 5). The result showed that the overall mean number of colonies holding was 4.12 and 0.64 colonies per household in traditional and modern beekeepers, respectively. The average colony holding of the traditional beehives was 5.38±1.72 in highland, 2.95±1.4 midland and 4.03±1.86 lowland. The average colony holding of modern beehives in the highland, midland and lowland was 0.28±0.78, 1.12±1.94 and 0.52±0.98 hives, respectively. Highly significant ($p<0.001$) difference was observed in mean colony holding in both traditional and modern beehives across the different agro ecologies. The average colony holding of both traditional and modern beehives with colony in the highland, midland and lowland was 1.05±2.62, 1.52±2.14 and 1.25±2.37 hives, respectively (Table 5).

Table 5: Average colony holding per household in the study area

Agro-ecology	Number of traditional hives with colony		Number of modern frame hives with colony		Number of both traditional and modern hives	
	Mean±SD	p-value	Mean±SD	p-value	Mean±SD	p-value
Highland	5.38±1.72	0.000	0.28±0.78	0.605	1.05±2.62	0.890
Midland	2.93±1.40	0.001	1.12±1.94	0.002	1.52±2.14	0.533
Lowland	4.03±1.86	0.000	0.52±0.98	0.039	1.25±2.37	0.814
Overall	4.12±1.94	0.000	0.64±1.37	0.002	1.27±2.38	0.562

N = Number of observation (N =180), SD = Standard Deviation

This result agrees with the findings of other researchers (Alemayehu, 2021; Bekele *et al*., 2017) in which the average colony holding was 4.76 to 6.26 colonies per head in Arba Minch Zuria district, southern region and Bale zone of Oromia region, Ethiopia, respectively. Highly significant ($p<0.01$) difference was observed in mean colony holding in both traditional and modern beehives across the three agro-ecologies. However, the current result was by far lower than the average colony holding observed in the Afar region (10.08 colonies per household) by Gebrehaweria *et al*., (2018). Kiros and Tsegay (2017) observed more than 40% of the beekeepers own both frame and traditional hives followed by only modern in eastern Tigray, Ethiopia. Similarly, beekeepers in central Tigray region had owned both traditional and modern as indicated by Haftu *et al*., (2015).

This result agrees with the findings of Alemayehu *et al. (*2016*)* who reported that highlands with dense forest and lack of access to modern box hives would have greater number of honeybee colonies in traditional hives in three agro-ecologies of Benishangul-Gumuz, Western Ethiopia. This argument was in contrast with Guesh *et al.*, (2018) who reported that the mean number of honeybee colonies managed under traditional hive in lowland and midland was significantly higher than that in highland agro-ecological zones in Tigray region, northern Ethiopia. Whereas, significantly large number of bee colonies in improved frame hive were found in highland and the number of colonies owned per household were significantly ($p<0.05$) different across the agro-ecologies. However, the number of improved frame hives owned by the sampled respondents in highland and midland were insignificantly difference. The greater number of honeybee colony in improved hives in highland and midland is probably because of strong intervention on beekeeping by government and non-government organizations (NGOs) in their willingness in the areas.

According to the survey result, the numbers of honeybee colonies in both hive types decreased in the last five years (2019 to 2023) in all agro-ecologies. The respondent explained that the modern hives in 2021 were theft even without bee colony and some of the frame hives were used as wooden material, fuel for food cooking and other purpose. Most of the modern frame beehives were looted and damaged by the Eritrean troops during the genocidal war.

4.2.4. Source of Honeybee Colony

Beekeeping as a business or activity needed to have a honeybee colony to start with where beginners should have got honeybee colony gift from parents, catching swarms, inheritance, NGOs, and bought from beekeepers. According to the beekeepers, 32%, 8% and 28% in highland, midland, and lowland agro-ecologies obtained bee colony from swarm catching, respectively. This further indicates that the study area has a potential and favourable environment for the bees to live. Likewise, about 30%, 7% and 15% of the beekeepers in highland, midland and lowland started beekeeping with a colony given from parents as a gift, respectively. Others acquired colonies from NGOs with 10% in highland and 17% in midland. Inheritance was also identified as source of honey bee colony in highland (7%) and midland (5%) in (Figure 5).

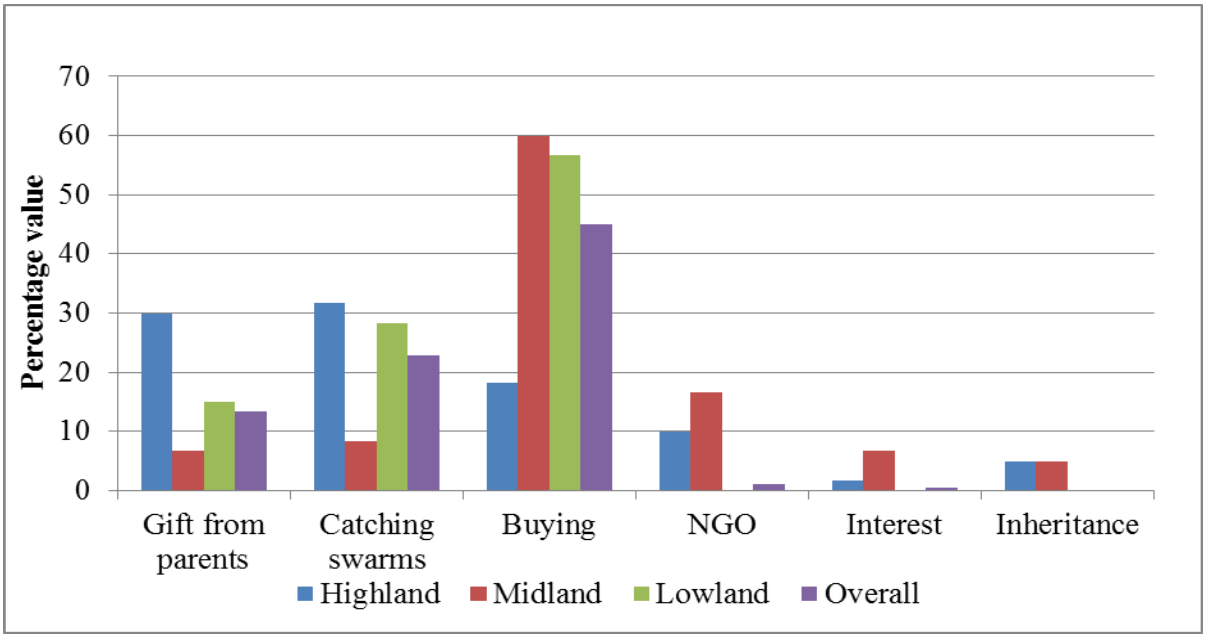

Figure 5: Sources of honeybee colonies in each agro-ecology of the study area

Majority of the respondents in highland got their colonies from swarm catching (relates with natural reproductive swarming resource) and gift from parents and the proportion of swarm catching was higher in highland (32%) and lowland (28%) than midland (8%). The study revealed that most of the beekeepers in highland areas use swarm catching to establish their foundation stock whereas buying in midland and lowland. This is due to the fact that farmers could catch colonies easily when reproductive swarming is active.

This finding agreed with the reports of Haftu and Gezu (2014) and Tilahun *et al*. (2016) who found that most beekeepers (51-60%) indicated that large number of small-scale beekeepers obtained their colony from swarm catching and the rest from their parents, purchasing and inheritance in Tigray region of Ethiopia. Similarly, other researchers (Bekele *et al*., 2017, Dinku, 2018, Kiros and Tsegay, 2017) found that majority of beekeepers started beekeeping through swarm catching in Bale zone, Jimma and Illubabor zone, and Sidama Zones, respectively.

This as it is, in midland (60%) and lowland (57%), majority of the respondent beekeepers got their bee colony by purchasing in the market place of Enticho and from the beekeepers in the highland areas. The result also showed that majority of the beekeepers got their colony through purchase in highland (18%), midland (60%) and lowland (57%). The result agrees with the findings of Guesh *et al*., (2018) who indicated that majority of the beekeepers obtained their establishing colonies by purchasing them from market places and other beekeepers, while the remaining got them as gift from parents and through catching swarms, using hanging bait hives on the apex of trees. The proportion of swarm catching was the highest in lowland and lowest in midlands. On the other hand, majority of the respondents from midlands and highlands got their bee colonies through purchase.

About 98% of the respondents agreed that bee colony selling is practiced in the study district with an average price of strong colony 3627 ETB and weak colony 2887 ETB during the surveying time 2023. The price of an established traditional colony differs from agro-ecology to agro-ecology, beekeeper to beekeeper, bee colony strength and bargaining power, ranging from 2500 to 4800 ETB (Table 6). The strong and weak colony preferred by their colony population, color, defensive behavior and number of comb building in the hive.

Table 6: Price of colony and beekeeping experience in the study area in the year 2023 (Mean±SD)

Agro-ecology	Price of strong colony	Price of weak colony	Beekeeping experience year
Highland	3085±358	2450±295	20.2±9.8
Midland	3744±836	3042±462	20.2±10.5
Lowland	4052±817	3170±971	15.7±7.1
Overall	3627±670	2887±576	18.7±9.4

N = Number of observations (N = 180), SD= Standard deviation

The study indicated that there is an increasing trend of bee colony price from time to time due to the increasing demand of bee colony and the increasing trend of a honey bee colony products and production in the study areas (Table 7). To increase the number bee colony holding size, majority (45%) of the beekeepers acquire through bought bee colonies and the rest through swarm catching, gift from parents, trained, inheritance and overcrowding. The result agrees with Addisu and Desalegn (2021) in the districts of south Wollo zone, Amhara, Ethiopia in which more than 94% of the respondents agreed that bee colony selling is practiced with an average price of 936.22 ETB. They added that the price of an established traditional colony differs from kebeles to kebeles or farmer to farmer according to bee colony strength ranging from 300 to 1500 ETB. The variation in price with the current finding could be due to spatial (location) and temporal (time) difference.

4.2.5. Honeybee Colony Placement and Survival Status

Generally, the suitable apiary selection to keep bee colony is far from different factors like the community, road, vehicle sound, machines, animals and other factors. It is an important consideration for productive beekeeping. Of the total sampled households, 100%, 37% and 20% placed their colonies at the backyard around the house in highland, midland and lowland, respectively. On the other hand, about 63% (midland) and 80% (lowland) placed their colony inside the residence house with small hole entrance in the home side (Table 7).

Table 7: Honeybee colony placement across each agro-ecology of the study area

Colony placement	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Backyard	60	100	22	36.7	12	20	94	52.2
Inside house	0	0	38	63.3	48	80	86	47.8
Total	60	100	60	100	60	100	180	100

N = Number of observations (N = 180)

All of the beekeepers kept their hives at back yard in highland, whereas majority of the colonies placed inside house in midland and lowland areas and no in enclosure area due war condition they take to their home. This could be simple for management and day to day service of supervision for beekeepers. Majority of the beekeepers (52%) placed their honeybee colonies at the backyard whereas about 49% placed their honeybee colonies inside house. This shows that backyard beekeeping is the most common practice in the study areas. The main reasons for beehive placement or apiary selection were close supervision and management, controlling from theft, and availability of bee flora.

This finding is in line with the research finding of other research works (Abebe, 2017, Gidey *et al*., 2012, Niguse, 2015 and Nebiyu and Messele, 2013) who reported that most beekeepers placed their honeybee colonies at backyard and inside the house in Tehulederie District of South Wollo Zone, Amhara Regional state, in Asgede Tsimbla district and, Eastern Zone of Tigray Regional State, North Ethiopia and in the three Agro ecological districts of Gamo Gofa zone of southern Ethiopia. Placing hive around homestead and in house apiary sites is appropriate for daily follow up of beekeeping activities (Birhanu, 2016). Similarly, Guesh *et al*. (2018) stated that majority of the beekeepers (76%) placed their honeybee colonies at the backyard, while about 11% placed in inside house in Tigray region. Similar result was reported by Yetimwork *et al*., (2015) who reported that about 12.8% of the respondents kept the traditional hive in the backyard followed by under the eaves of the house (2.60%), in the house with family (1.90%) and in area closure (1.30%) in Eastern Zone of Tigray, Ethiopia.

Honeybee colony survival status was a maximum of 34 and 13 years in traditional and modern hive in highland, 30 and 26 years in traditional and modern hive in midland and 30 and 20 years in traditional and modern hive in lowland, respectively (Table 8). This might be due to the distribution of frame hives without full technological packages (training and improved beekeeping accessories) which should be given due attention, weak extension services, and demand for its own seasonal management techniques and other accessory equipment, lack of knowhow.

Table 8: colony survival status in tradition and modern hives in the study area

Agro- ecology		Survival status of honeybee colony			
		Minimum		Maximum	
		Traditional hive	Modern hive	Traditional hive	Modern hive
Highland	Minimum	1	0	2	0
	Maximum	10	5	34	13
	Mean±SD	3.3±2.1	75±1.5	9.3±7.5	1.98±3.7
Midland	Minimum	0	0	0	0
	Maximum	20	22	30	26
	Mean±SD	4.95±4.6	11.9±7.9	11.9±7.9	4.73±6.6
Lowland	Minimum	1	0	5	0
	Maximum	10	4	30	20
	Mean±SD	3.78±1.7	0.78±1.4	8.65±4.4	1.87±3.6
Overall	Minimum	0	0	1.43±3.10	0
	Maximum	20	22	34	26
	Mean±SD	4.01±3.1	1.43±3.1	9.95±6.9	2.86±5.1
p-value		0.010	0.020	0.000	0.000

N = Number of observations (N = 180), SD= Standard deviation

4.2.6. Advantage of Beekeeping over the Other Agricultural Activities

The primary means of livelihood in the study areas is mixed crop-livestock farming system. Beekeeping is suitable business for poor and landless farmers. This could be due to the fact that beekeeping operation requires small initial capital with possibility of keeping honeybee in marginal lands where crop production is no possible and even young people who have no available farm lands. The same fact was raised during discussion with key informants. Besides, crop production, livestock and other off-farm activities such as irrigation and other farming are also available means to support their subsistence livelihood. The possibility of keeping honeybee side by side along with on-farm and other off-farm activities is very important in the use of beekeeping in the household. The survey results indicated that about 100%, 53% and 25% of the households see beekeeping as main income in highland, midland and lowland areas, respectively, while 47% and 75% considered as side line business in midland and lowland areas, respectively in the use of the household (Table 9).

Table 9: Advantages of beekeeping in the study area

Use of beekeeping	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Main income	60	100	32	53.4	15	25	107	59.4
Side activity income	0	0	28	46.7	45	75	73	40.6
Total	60	100	60	100	60	100	180	100

N = Number of observations (N = 180)

The sampled respondent ranked beekeeping, crop production and livestock activities as the first, second and third sources of income in highland, respectively, while crop production, livestock production and beekeeping ranked first, second and third in both midland and lowland areas (Table 10).

Table 10: Ranking index of beekeeping as a main income sources for livelihood in the study area

Farming type	Agro-ecology											
	Highland			Midland			Lowland			Overall		
	N	Index	Rank	N	Index	Rank	N	index	Rank	N	Index	Rank
Crop	57	0.33	2	33	0.34	1	26	0.43	1	116	0.367	1
Livestock	57	0.33	3	33	0.33	2	18	0.30	2	108	0.32	2
Beekeeping	60	0.35	1	33	0.33	2	16	0.27	3	109	0.317	3

N= Number of observations

The overall results showed that crop cultivation, livestock rearing and beekeeping are important activities in the order of their importance in the district. During the survey, all of the beekeepers (100%) replied that beekeeping is more profitable in their locality and this indicates that most of the beekeepers in the study area undertake beekeeping to generate cash income from the sale of honey and honeybee colony. This result agrees with the result of Alemayehu (2021) who reported that crop production, livestock production and beekeeping were ranked as first, second and third sources of income, respectively in Arba Minch Zuria of southern Ethiopia. Likewise, Kalayu *et al*., (2017) and Dinku *(*2018*)* noted that beekeeping ranked third source for household income in North East dryland areas of Amhara region and Sidama zone of southern region of Ethiopia, respectively.

4.2.7. Local Honeybee Colony, their Behavior and Body Size

The sampled beekeepers included all the sample respondents own three or more honeybee colony. Accordingly the beekeepers identified and characterized the honeybee colony types based on the honeybee behaviour, body size and colour. The beekeepers categorized the honeybee colony types into aggressive, docile and very aggressive behavioural characteristics of honeybee colonies exist in all agro-ecologies. Accordingly, from the three honeybee colony owned by the respondent beekeepers about 97%, 87% and 88% of the respondent beekeepers own aggressive honeybee colonies in highland, midland and lowland, respectively. About 87%, 93% and 100% of the beekeepers own docile honeybee colonies in the same order, while 55%, 13% and 15% of them own very aggressive honeybee colonies in highland, midland and lowland areas, respectively (Table 11).

All the beekeepers in the sample own three or more honeybee colonies and then, categorized their colony based on their colour into black, red and mixed. Accordingly, about 95%, 87% and 90% of the beekeepers own black coloured honeybee colonies in highland, midland and lowland areas, respectively. About 70%, 87% and 100% of the beekeepers own red coloured honeybee colonies in highland, midland and lowland areas, respectively, while 35%, 47% and 45% of them own mixed coloured honeybee colonies, which is the mixture of red and black coloured local honeybees (Table 11).

Table 11: Phenotypic characterization of honeybee colonies in each agro-ecology

Major characteristics of honeybee colony		Agro-ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Behavior	Docile	52	86.7	56	93.3	60	100	168	93.3
	Aggressive	58	96.7	52	86.7	53	88.3	164	90.6
	Very aggressive	33	55.0	8	13.3	9	15	50	27.8
Body colour	Black	57	95.0	52	86.7	54	90	166	90.6
	Red	42	70.0	52	86.7	60	100	154	85.6
	Mixed	21	35.0	28	46.7	27	45	76	42.2
Body Size	Small	37	61.7	52	86.7	48	80.0	137	76.1
	Medium	26	43.3	10	16.7	24	40.0	60	33.3
	Big	29	48.3	44	73.3	48	80.0	121	67.2

N = Number of observations

The third criteria that the beekeepers used to identify the characteristics of the honeybees were based on body size and based on this they classified into three categories, namely big, medium and small sized honeybee colonies. Accordingly, about 48%, 73% and 80% of the sampled beekeepers own big sized honeybee colony in highland, midland and lowland areas, respectively, while 62%, 87% and 80% of them own small sized honeybee colony in the same order. Likewise, about 43%, 17% and 40% of them own medium sized honeybee colony in that order (Table 11).

As per the respondents, the black honeybee type is recognized as aggressive behaviour and small sized, while the red honeybee type is categorized as docile behaviour and big sized. The mixed coloured colony has medium body size and is considered to be the hybridized of red and black bee type. The result revealed that black coloured bee colony is highly available in highland, while red coloured bee type is commonly available at lowland.

The result indicated that the black bees are more preferred by beekeepers as compared with red and mixed bees in highland areas. According to the respondents, the black bees are more defensive than red coloured and high reproductive performance (frequently give reproductive swarm, honey yield and pests and predators resistant). This result is in good agreement with the findings of Kiros and Tsegay (2017*)* in eastern Tigray, Ethiopia who reported the beekeepers claimed that there was a strong positive relationship between characteristics and productivity of bee. Accordingly, aggressive bee is better productivity than docile bee. This might be the aggressive bee was defensive to their tertiary than docile character colonies as reported by Kiros and Tsegay (2017*)* in eastern Tigray, Ethiopia.

Moreover, the black local honeybees construct good quality white coloured comb honey, which is attractive in market. The colour may be determined by availability of good honeybee flowers. They also highly defend their hives against other intruder animals without the help of beekeeper. According to the beekeepers' response, suitable honeybee ecotype is usually defined in terms of its ability of gathering large amount of honey yield and its potential for management and manipulation. Whereas, the red bees more preferred in the lowland areas as compared with black and mixed bees due to gentleness and quietness on the combs (Tessema and Zeleke, 2017) in

Eastern Amhara Region, Ethiopia. There exists great variation in the honeybees, which lies high potential for selecting the genetic stock easier to manage and maintain inherent advantages.

The honeybee colonies found in highland were abundantly dark in colour, small in size, aggressive, adapted to the cold condition, active, productive and have fewer enemies, whereas the honeybee colonies in lowland are abundantly red in colour, larger in size, docile in behaviour, and adapted to the areas. Similarly, the honeybee colony productivity and behavioural characteristics are highly affected by physical environment (altitude, vegetation, and climate). This result agrees with the result of Hailu (2022) who reported greater proportion of the buyers showed the preferences between black, yellowish red and hybrid honeybee colony in Ahferom district of Tigray region, northern Ethiopia. A large proportion of respondents prefer black coloured bee colony from highland originated at the same study area in Enticho honeybee colony marketing area.

4.3. Honeybee colony performance characteristics

4.3.1. Honeybee Colonies and their Performance

The beekeepers identified and characterized the colony types based on the honeybee behaviour, body size and colour. Beekeepers evaluate the three categories of colonies with respect to honey yield, dry season brooding ability, colony strength, hygienic behaviour, foraging ability, pests and predators resistance, drought resistant, swarming tendency and absconding behaviour.

The black bees which are dark in colour, small in size, and aggressive in behavior evaluated by the beekeepers as first in honey yield, dry season brooding ability, colony strength, foraging ability, pests and predator resistance, drought resistant and swarming tendency followed by red coloured bees (Table 12-14). The black coloured bees were primarily ranked the highest in swarming tendency (80%) in highland areas. The discussant beekeepers also explained that the black coloured bees are easier in multiplication for splitting due to their high swarming tendency and bee population. On the contrast, the red bees which are red in colour, larger in size, docile in behavior have the highest absconding behavior as compared with dark bees. .

In favour of this study, Tilahun *et al., (*2016*)* observed that the black coloured bees rose first in honey production according to the interviewed beekeepers in lowland and midlands areas of

Tigray, northern, Ethiopia. The authors added that the black coloured bees were ranked the highest in swarming tendency, honey yield with high brooding ability, resistant to drought during the dry season, resistant to enemy attacks that cause the bees to abscond. Whereas in contrast with the result explained, the red coloured bees were preferred to black and mixed colours for honey production in midlands. In general, beekeepers' experience in Tigray region showed that the external body colour of honeybee colonies is highly related to production performance parameter.

This as it is, some beekeepers believe that bee colonies have their own strong and weak behaviours, however, improving management can increase colonies productivity performance. Based on the result, evaluation of different strains of honeybees at their original ecology is important to use their potential and to lay foundation for future selection and improvement of local honeybee races.

Table 12: Characterization of honeybee colony and their performance based on body colour

Performance parameters of honeybee colony		Agro-ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Honey yield	Black	54	90.0	39	65.0	32	53.3	125	69.4
	Red	6	10.0	8	13.3	20	33.3	34	18.9
	Mixed	0	0	13	21.7	8	13.3	21	11.7
Brooding ability	Black	53	88.3	35	58.3	31	51.7	119	66.1
	Red	7	11.7	14	23.3	17	28.3	38	21.1
	Mixed	0	0	11	18.3	12	20.0	23	12.8
Colony strength	Black	50	83.3	36	60.0	31	51.7	117	65.0
	Red	10	16.7	10	16.7	20	33.3	40	22.2
	Mixed	0	0	14	23.3	9	15.0	23	12.8
Hygienic behaviour	Black	51	85.0	42	70.0	34	56.7	127	70.6
	Red	9	15.0	7	11.7	16	26.7	32	17.8
	Mixed	0	0	11	18.3	10	16.7	21	11.7
Foraging ability	Black	48	80.0	32	53.3	35	58.3	115	63.9
	Red	12	20.0	13	21.7	18	30.0	43	23.9
	Mixed	0	0	15	25.0	7	11.7	22	12.2
Pests and predators Resistant	Black	54	90.0	42	70.0	35	58.3	131	72.8
	Red	6	10.0	6	10.0	16	26.7	28	15.6
	Mixed	0	0	12	20.0	9	15.0	21	11.7
Swarming tendency	Black	48	80.0	33	55.0	29	48.3	110	61.1
	Red	12	20.0	11	18.3	21	35.0	44	24.4
	Mixed	0	0	16	26.7	10	16.7	26	14.4
Absconding tendency	Black	0	0	13	21.7	23	38.3	36	20.0
	Red	53	88.3	44	73.3	36	60.0	133	73.9
	Mixed	7	11.7	3	5.0	1	1.7	11	6.1

N = Number of observations

Table 13: Characterization of honeybee colony and their performance based on their body size

Body size of honeybee colony		Agro-ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Honey yield	Big	4	6.7	8	13.3	12	20.0	24	13.3
	Medium	26	43.3	12	20.0	14	23.3	52	28.9
	Small	30	50.0	40	66.7	34	56.7	104	57.8
Brooding ability	Big	6	10.0	12	20.0	11	18.3	29	16.1
	Medium	14	23.3	10	16.7	17	28.3	41	22.8
	Small	40	66.7	38	63.3	32	53.3	110	61.1
Colony strength	Big	7	11.7	6	10.0	11	18.3	24	13.3
	Medium	20	33.3	13	21.7	13	21.7	46	25.6
	Small	33	55.0	41	68.3	36	60.0	110	61.1
Hygienic behaviour	Big	9	15.0	9	15.0	14	23.3	32	17.8
	Medium	23	38.3	8	13.3	15	25.0	46	25.6
	Small	28	46.7	43	71.7	31	51.7	102	56.7
Foraging ability	Big	13	21.7	12	20.0	13	21.7	38	21.1
	Medium	21	35.0	14	23.3	12	20.0	47	26.1
	Small	26	43.3	34	56.7	35	58.3	95	52.8
Pests, diseases resistant	Big	6	10.0	6	10.0	9	15.0	21	11.7
	Medium	16	26.7	9	15.0	16	26.7	41	22.8
	Small	38	63.3	45	75.0	35	58.3	118	65.6
Swarming tendency	Big	8	13.3	10	16.7	16	26.7	34	18.9
	Medium	22	36.7	10	16.7	8	13.3	40	22.2
	Small	30	50.0	40	66.7	36	60.0	106	58.9
Absconding tendency	Big	48	80.0	45	75.0	36	60.0	129	71.7
	Medium	12	20.0	6	10.0	4	6.7	22	12.2
	Small	0	0	9	15.0	20	33.3	29	16.1

N = Number of observations

Table 14: Characterization of honeybee colony and their performance based on their behaviour

Behavioural characters of honeybee colony		Agro ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Honey yield	Docile	7	11.7	15	25.0	14	23.3	36	20.0
	Medium	0	0	5	8.3	7	11.7	12	6.7
	Aggressive	53	88.3	40	66.7	39	65.0	132	73.3
Brooding ability	Docile	12	20.0	15	25.0	16	26.7	36	20.0
	Medium	0	0	11	18.3	9	15.0	12	6.7
	Aggressive	48	80.0	34	56.7	35	58.3	132	73.3
Colony strength	Docile	6	10	15	25.0	14	23.3	35	19.4
	Medium	0	0	6	10.0	8	13.3	14	7.8
	Aggressive	54	90.0	39	65.0	38	63.3	131	72.8
Hygienic behaviour	Docile	10	16.7	12	20.0	16	26.7	38	21.1
	Medium	0	0	9	15.0	11	18.3	20	11.1
	Aggressive	50	83.3	39	65.0	33	55.0	122	67.8
Foraging ability	Docile	5	8.3	12	20.0	12	20.0	29	16.1
	Medium	6	10.0	11	18.3	9	15.0	26	14.4
	Aggressive	49	81.7	37	61.7	39	65.0	125	69.4
Pests and predators resistance	Docile	5	8.3	13	21.7	16	26.7	34	18.9
	Medium			11	18.3	7	11.7	18	10.0
	Aggressive	55	91.7	36	60.0	37	61.7	128	71.1
Swarming tendency	Docile	13	21.7	10	16.7	21	35.0	44	24.4
	Medium	0	0	12	20.0	0	0	12	6.7
	Aggressive	47	78.3	38	63.3	39	65.0	124	68.9
Absconding tendency	Docile	53	88.3	42	70.0	37	61.7	132	73.3
	Medium	5	8.3	2	3.3	3	5.0	10	5.6
	Aggressive	2	3.3	16	26.7	20	33.3	38	21.1

N = Number of observations

4.3.2. Honey Production, Harvesting Frequency and Season

The current result confirmed that honey yield varied with hive types and agro-ecologies. As a result, the beekeepers harvested an average honey yield of 7.17±6.08, 15.17±2.61 and 16.62±3.06 kg/hive/year in highland, midland and lowland from traditional hive, respectively. Likewise, about 14.73±9.14 (highland), 22.26±3.83 (midland) and 24.21±5.98 kg/hive/year (lowland) honey is harvested from modern hive. The present findings indicated that hive types and agro-ecology have impact on honey yield performance. Significant variation was observed between traditional and modern hive in honey yield in all ecologies ($p<0.05$). Higher amount of honey productivity was recorded in lowlands and midlands than in highlands in both traditional and modern hives. Lowlanders harvest more honey than that of midlanders in both hive types.

The overall mean honey yield was 15.48±3.65 and 21.46±6.89 kg/hive/year in traditional and modern hives, respectively in the district. Highly significant difference ($p<0.001$) was observed in honey yield in both traditional and modern bee hives, whereas insignificant difference ($P<0.05$) in highland from modern hive (Table 15).

Table 15: Honey yield of traditional and modern hives in the study area in the year 2023

Agro-ecology	Honey yield (kg /hive/year)							
	Traditional hives				Modern frame hive			
	Min	Max	Mean±SD	P-value	Min	Max	Mean± SD	P-value
Highland	3	15	7.17±6.08	0.032	4	30	14.73±9.14	0.483
Midland	9	20	15.17±2.61	0.000	15	30	22.26±3.83	0.001
Lowland	13	25	16.62±3.06	0.000	10	35	24.20±5.98	0.000
Overall	3	25	15.48±3.65	0.000	4	35	21.46±6.89	0.000

Min = Minimum, Max = Maximum, SD = Standard deviation

The highest honey yield obtained from traditional hive was recorded in lowland areas compared to midland and highland areas. Regarding the honey productivity of modern beehives, the highest honey yield was recorded in lowland, while the lowest honey yield was recorded in highland areas of the district. The amount of honey obtained from traditional and improved movable frame beehives was higher than the national average honey yield stated by CSA (2017), 9.2 kg and 19.1 kg, respectively. This implies that lowlands and midlands are most favorable for honey production.

Comparative result was obtained by Godifay (2015) with 10.38±4.45 kg of honey from the traditional beehives and 26.53±8.75 kg from improved movable frame hives per harvest, respectively. Gidey and Mekonen (2010) found 8-15 kg and 20-30 kg of honey from traditional and improved movable frame beehives in selected zones of Tigray region, Northern Ethiopia, respectively. According to the report of Gebregiorgis *et al*. (2018), the annual production of honey per traditional hive was significantly higher in Saesiea-Tsaeda-Emba (11.42±1.77 kg), Atsib-Wemberta (10.55±0.84 kg) and Hawzen (10.15±1.36 kg) than Degua-Timben (7.88±1.40 kg) and the production of honey per modern hive was significantly higher in Atsib-Wemberta (35.33±2.20 kg), Hawzen (33.05±1.94 kg), and Degua-Timben (28.60±0.55 kg) than Saesiea-Tsaeda-Emba (23.22±1.81 kg) in four districts of Tigray region, Northern Ethiopia.

The current findings indicated only few of the hive holders (3.3%) produce wax from beehives. This agrees with the result of Tizazu (2018) who reported that two of the beekeepers started to use beeswax and even have knowhow about this product in Sayo district of western Oromia, Ethiopia.

The honey harvesting frequency showed that about 10%, 47% and 83% of the beekeepers in highland, midland and lowland harvest their hive once per year, respectively from traditional hive. Likewise, about 45% and17% in midland and lowland harvest their colony twice per year, respectively. Whereas from modern hive, 85%, 34% and 37% in highland, midland and lowland areas harvest their hive once per year, respectively and about 15%, 65% and 62% in highland, midland and lowland harvest their colony twice per year, respectively. Majority of the beekeepers (47%) collect honey once, 21% twice in a year from traditional hive, whereas 33% of the respondents did not harvest honey from traditional hive. Majority of the respondent beekeepers (55%) harvest honey twice and 45% harvest honey once from modern hive (Figure 6).

In traditional hives, most beekeepers harvest honey once a year and followed by twice a year. In the modern hives, majority beekeepers harvest honey twice followed by once a year. The results were highly significant ($p<0.001$) in both hive types across each agro-ecology, whereas not significant in midland areas ($p<0.05$) in modern hive. The highest honey harvesting frequency was observed in midland as compared to highland and lowlands agro-ecological zones.

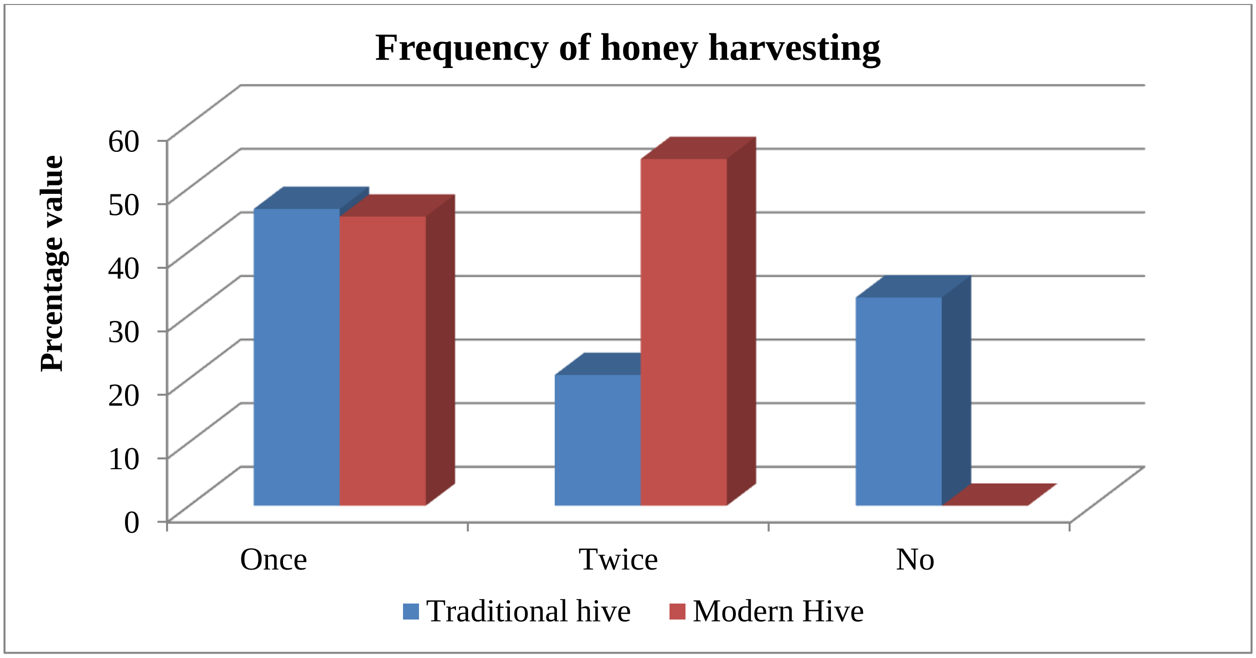

Figure 6: Frequency of honey harvesting in the study area

The honey harvesting months are at September to November (28%), March to May (5%) and June to August (17%) in highland. In addition, 97%, 7% and 93% of the beekeepers collect honey at September to November, May to March and June to August, respectively in midland and 100%, 3% and 62% at September to November, March to May and June to August, respectively in lowland areas. The main honey harvesting months are September to November and June to August in all agro-ecological zones. Whereas, the minor honey harvesting months are March to May. During the major honey harvesting months, the beekeepers could harvest honey twice in a month if the season is blessed with sufficient rainfall.

This result is in line with Guesh *et al*., (2018) who reported that most of the respondents harvested honey once followed by twice a year and the major honey harvesting months were September to November in all agro-ecological zones of Tigray. However, the minor honey harvesting months were June to August and the highest honey was observed in highlands as compared to midland and lowland areas of Tigray.

The frequency of honey harvest and amount of honey produced per production season varied with different agro ecologies. The frequency and amount of honey harvested varied among the year of productions depending on seasonal colony management practices, skill of beekeepers, flowering condition of major bee forage with rainfall, weather condition and type of beehive.

4.3.2.1. Trends of Honeybee Production and Number of Bee Colony

During the past five years (2019-2023), there has been dynamism in honey production and number of bee colonies. As per the respondents, the annual honey production showed decreasing (71%), increasing (1%), stable (7%) and unknown (21%) trends during the specified period (Figure 7). The honey yield reduction was bigger in lowlands and midlands as compared to that of highlands. This could be due to increased number of bee colonies using reproductive swarming in the highland as per the focus group discussants.

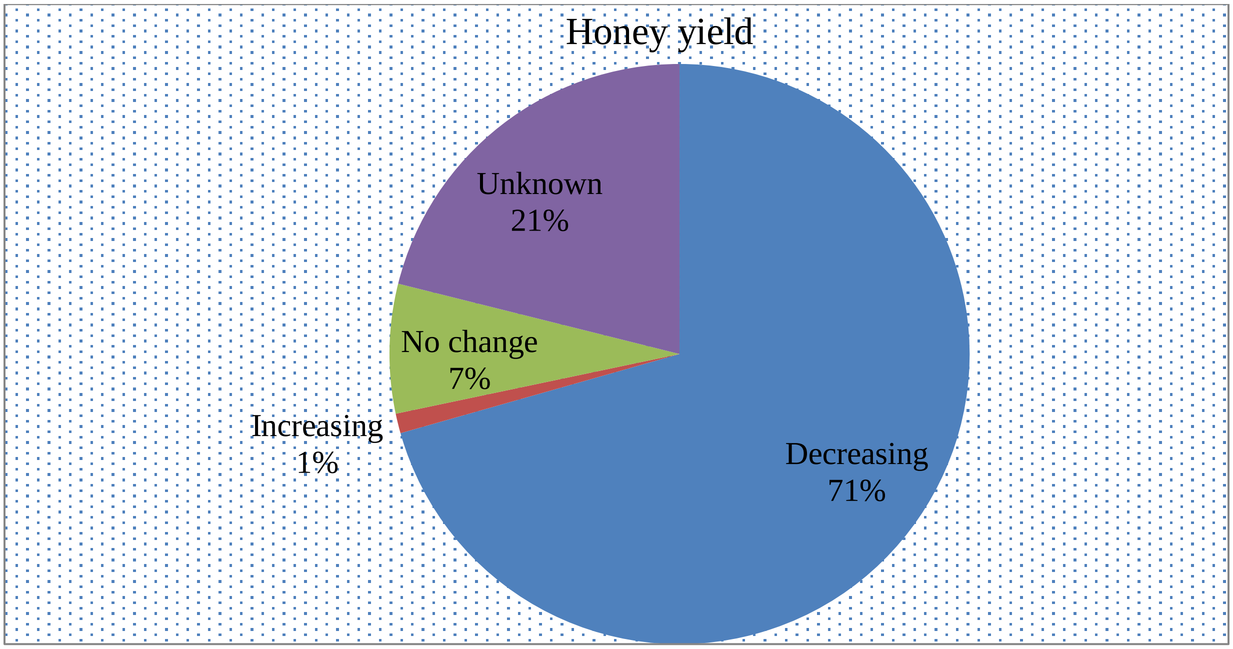

Figure 7: Condition of honey yield in the study area

The trends in number of bee colony in both hive types during the period from 2019 to 2023 production years showed a decreasing (70%), increasing (20%), and stable status (10%) trends (Figure 6). Majority of the beekeepers recognized that the number of honeybee colony remains decreased in highland (70%), midland (63%) and lowland (76%) figure 8.

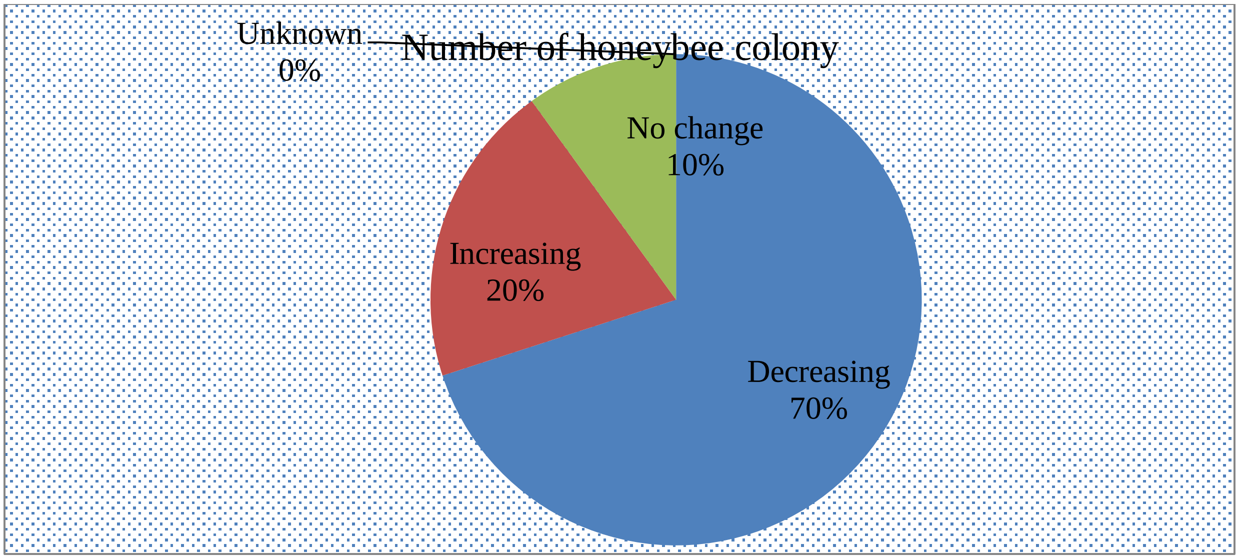

Figure 8: Condition of honeybee colony in the district

This result is in line with the result of other researchers (Alemu, 2015; Dinku, 2018) who noted that majority of beekeepers (79-85%) in Sidama zone, South Wollo and Waghimra Zones of Amhara region responded decreasing trend in number of honeybee colonies and their products over the past years due to indiscriminate use of agro-chemicals, shortages of bee forages and the availability and occurrence of various threatening factors which had an adverse effect on honeybee health and their production potentials.

As per the respondents, shortage of bee forage, pests and predators, drought, pesticide and herbicide application, post war effect were identified as the main cause for the reduction of honeybee products and number of colonies. The impact of each factor varies with agro-ecological zones. The causes for decreasing trend were post war effect (98%), shortage of bee forages (94%), pesticides and herbicide application (93%), pests and predators (93%) and drought (88%) in order of their importance.

The result is in contrast with Yetimwork *et al*. (2015) who revealed that in both traditional and framed hives, colony number showed increasing trends from time to time in Eastern Zone of Tigray, Ethiopia. For both traditional and framed beehives 8%, 4% and 5% and 82%, 1% and 13% responded as colony number is increasing, stable and decreasing, respectively. Similarly, Guesh *et al*. (2018) reported that majority (72%) of the beekeepers declared that honey production varies among the years in different agro-ecological zones of Tigray region, Northern Ethiopia.

The production of honey yield from traditional hive showed decreasing trends across the consecutive years from an average of honey 7.5 kg/hive/year (2019) to 5.83 kg/hive/year (2023), showing 22% reduction. Annual honey yield reduced from 96.33 kg/year (2019) to 25.17 kg/year (2023), showing 74% reduction in highland and high reduction had been observed (1.33kg/hive/year), indicating 82% decrement and total annual honey yield (2.35kg/year), and showing 98% reduction in highland. An average of honey yield decreased from 16.32 kg/hive/year (2019) to 8.67 kg/hive/year (2023), indicating 47% reduction and annual honey yield reduced from 65.91 kg/year (2019) to 28.37 kg/year (2023) in midland, showing 57% reduction and a mean of honey yield from 21.22 kg/hive/year (2019) to 3.42 kg/hive/year (2023), indicating 84% decrement and total annual honey yield lowered from 107.80 kg/year (2019) to 14.2 kg/year (2023) in lowland, showing 87% reduction. From traditional hive, honey production was highly significant different ($P<0.001$) in all agro-ecologies in terms of honey yield, however insignificant difference ($p<0.05$) in 2021 in total annual honey yield (Figure 9).

The result indicates that honey yield from traditional hive showed decreasing trend across time from 18.28 kg/hive/year (2019) to 5.97 kg/hive/year (2023), showing 67% reduction. Similarly, the honey production per year per household revealed reducing trend from 87.84 kg/year in 2019 to 21.30 kg/year in 2023, indicating 76% decrement. The honey yield from traditional hive showed rapid dropping in highland because there were high damage during the genocidal war by Eritrean troops than lowland areas they related the troops with gene family in Egella at the boarder of Eritrea but not in the other areas.

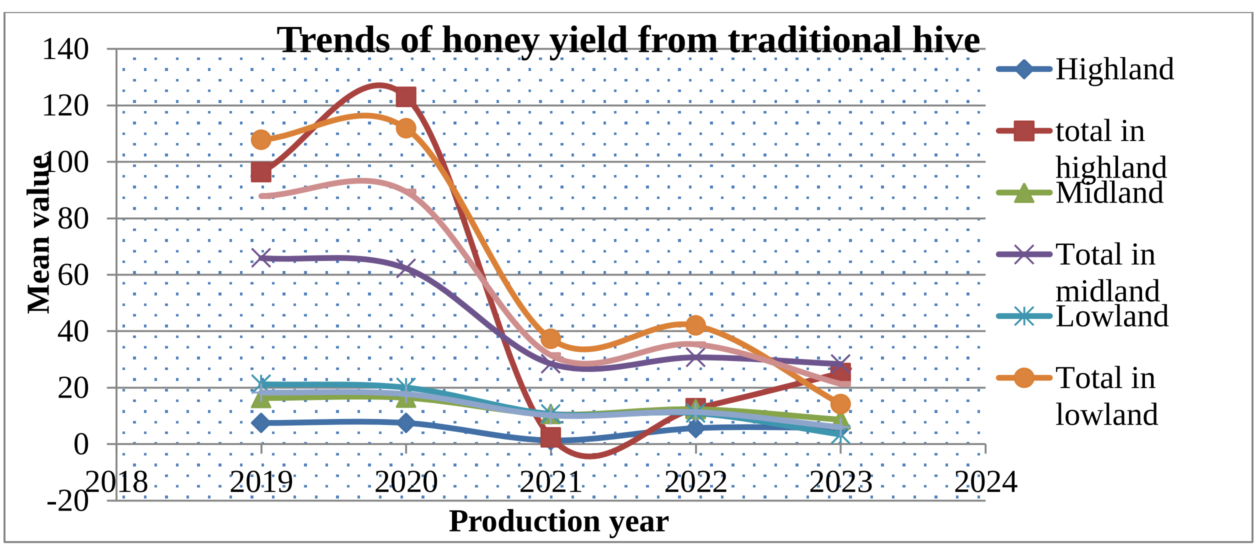

Figure 9: Trends of honey yield from traditional hive in each agro-ecology of the study area

The honey production yield from modern hive showed an average of honey yield reduction from 12.39 kg/hive/year (2019) to 2.46 kg/hive/year (2023), showing 80.2% reduction and a total annual honey yield decreased from 26.85 kg/year (2019) to 7.85 kg/year (2023), showing 70.76% reduction and highly serious reduction has observed the total annual yield to 4.08 kg/year (2021) 84% reduced in highland. An average of honey yield reduced from 26.75 kg/hive/year (2019) to 13.46 kg /hive/ year (2023), shows 50% reduction and a total annual honey yield lowered from 97.25 kg/year (2019) to 34.607 kg/year (2023), showing 64% and highly serious reduction has observed honey yield to 5.5 kg/hive/year(79%) and total annual honey yield 9.429 (90%) in 2021 in midland and an average of honey yield reduced from 26.8 kg/hive/year (2019) to 6.28 kg/hive/year (2023), sowing 77% reduction and a total annual honey yield lowered from 73.44 kg/year (2019) to 14.6 kg/year (2023), showing 80% reduction in lowland (Figure 10).

The result indicates that honey yield from modern hive showed decreasing trend across time from 23.94 kg/hive/year (2019 G.C) to 8.58 kg/hive/year (2023 G.C), showing 64% reduction. Similarly, the annual honey production per year per household revealed reducing trend from 74.36 kg/year to 21.76 kg/year, with 71% reduction across time 2019 to 2023.

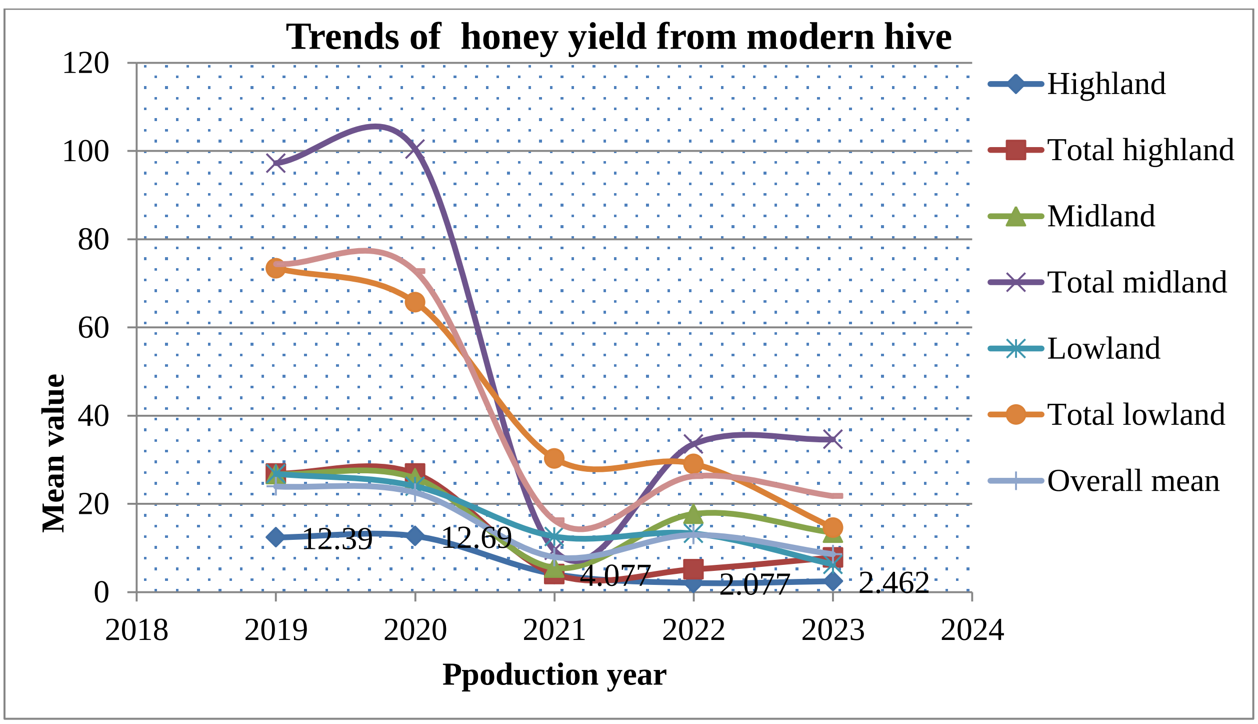

Figure 10: Trends of honey yield from modern hive in each agro-ecology of the study area

The result agrees with findings of Alemayehu *(*2021*)* who reported that the total honey yield from both traditional hive and modern hives have revealed undulating trend across the five consecutive years but generally confirmed decreasing trend of honey yield in traditional beehives. Considering the trend of total honey yield in both hives, it is also showed decreasing from 7469 kg in the year to 7336 in the year 2018 in Arba Minch Zuria District, Southern Ethiopia.

The honeybee colony number in traditional hive showed decreasing trends in consecutive years from an average number of honeybee colony 7.58 (2020) to 5.17 (2023), indicating 32% reduction. It was lowered to 3.37 (56% decrement) in highland, from 3.78 (2019) to 2.95 (2023) (22% reduction) in midland, and from 5.03 (2019) to 4.02 (2023) (20% less) in lowland (Figure 11).

The overall mean number of honeybee colony demonstrated decreasing trend in five consecutive years from an average of 5.47 (2019) to 4.04 (2023), showing 26% decrement and highly reduced in 2021 to 3.23 colony, indicating 47% colony reduction in traditional hive.

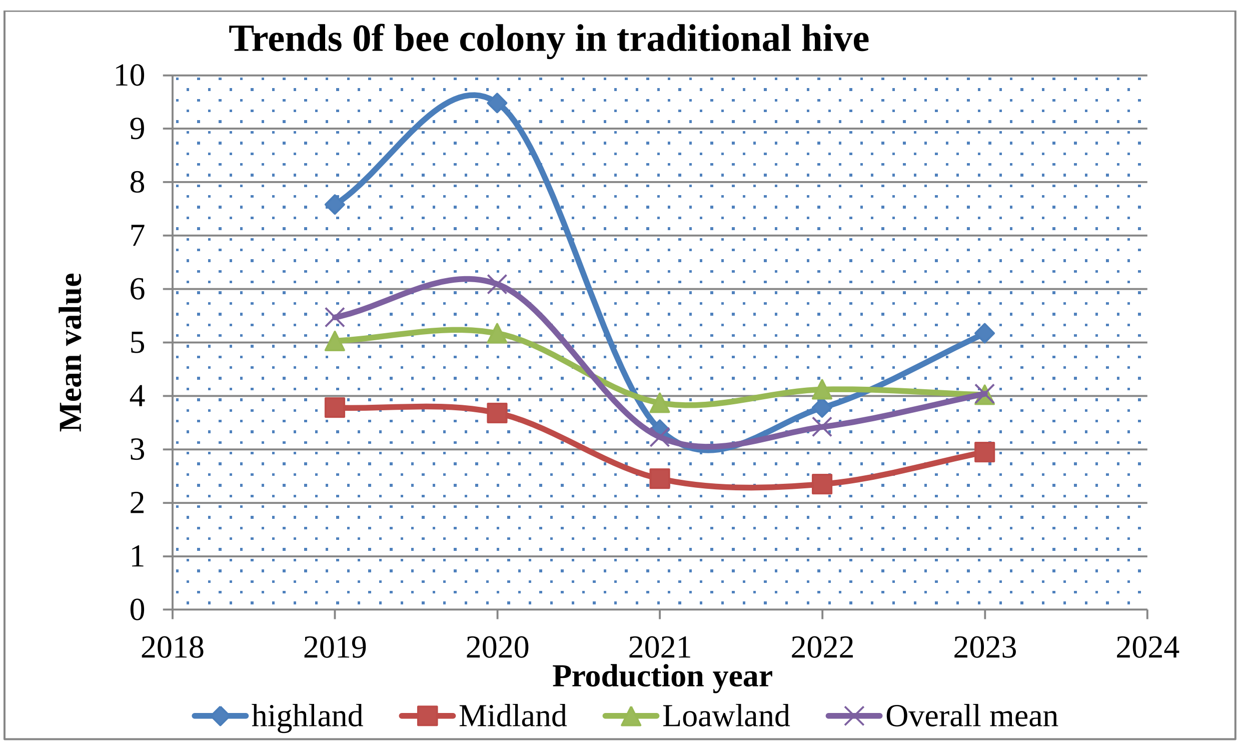

Figure 11: Trends of honeybee colony in traditional hive in each agro-ecology of the study area

In the last five years, the number of bee colony declined from 0.60 (2019) to 0.23 (2023) in modern hive. The number reduced to 0.12 (80% less) in 2021 in highland. Similarly, the colony holding reduced from 1.68 (2019) to 1.12 (2023) (33% decrement) in midlands. The reduction was more pronounced in 2021 with 0.58 colony holding (66% less). In lowlands, the number of colonies lowered from 1.22 (2019) to 0.52 (2023), indicating 57% reduction (Figure 12).

The overall mean number of honeybee colony demonstrated decreasing trend in five consecutive years from an average of 1.17 (2019) to 0.62 (2023), indicating 47% decrement and highly reduced in 2021 to 0.44 colony (62% lower) in modern hives.

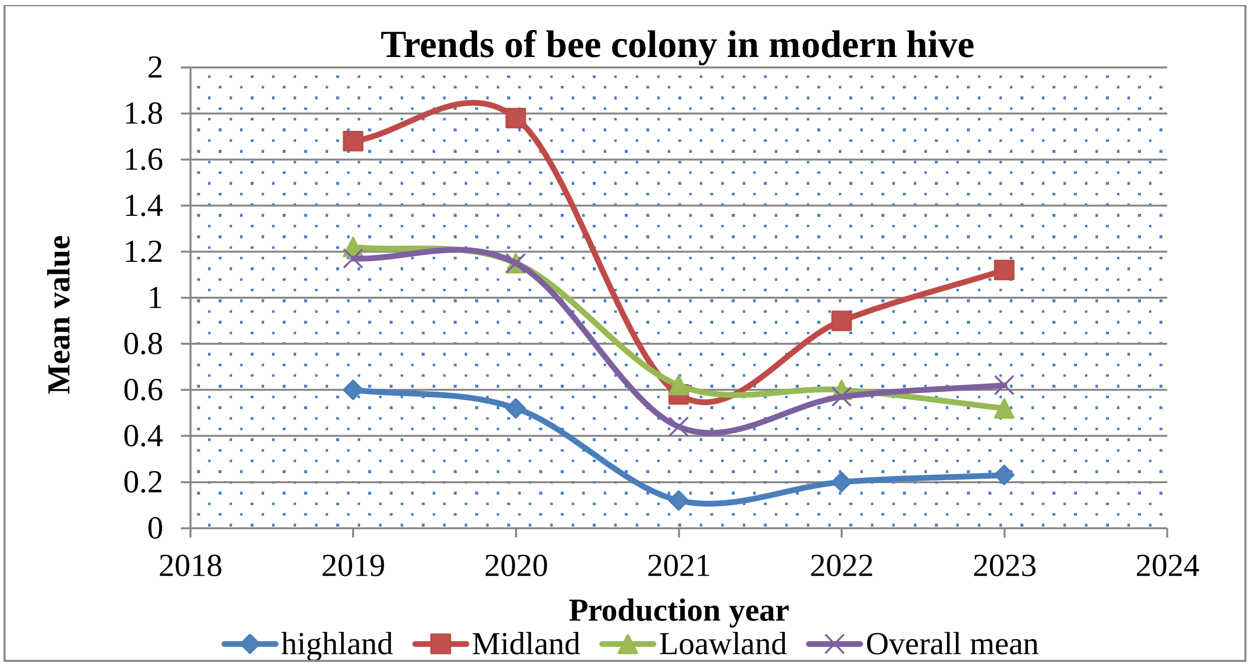

Figure 12: Trends of honeybee colony in modern hive in each agro-ecology of the study area

The current result is consistent with Alemayehu (2021) who reported that the trend of the total honeybee colony size across the last five years in both traditional and modern beehives showed decreasing trend in Arba Minch zuria district, southern Ethiopia. The author also mentioned the most limiting factors for colony number reduction, among which irresponsible utilization of agrochemicals, absconding, lack of bee forage and pests and predators.

4.3.2.2. Marketing of Honey and Other Hive Products

In the study area, processing of crude honey into table honey, crude beeswax into pure form and collection of propolis is not practiced by the beekeepers. Only few beekeepers (3%) collect crude beeswax from their apiary. On average, a beekeeper collects 0.075 kg crude beeswax and used as a candle light at home or give the produce as an offer to Orthodox churches. Consequently, beeswax is not often harvested for market in the study areas, but only few farmers do so for home use. The major reason was lack of knowledge of its use (97%), lack of processing skill how to harvest it (97%) and lack of processing material (94%). Likewise, the beekeepers did not have knowhow about propolis (locally known as *Melgi*) collection. In general, collecting and selling of beeswax and other hive products is not common in the study areas. The beekeepers are only aware of honey, bee colony and wax production. Similar observations were reported by other researchers in different parts of Ethiopia in which all beekeepers produce honey and few produce beeswax (Alemayehu and Abera, 2017, Nebiyu and Messele, 2013, Tizazu, 2018). This implies that future beekeeping intervention is very crucial in the area on bee products diversification to contribute to improved livelihoods of the community.

The major product of beekeeping sold to market in Ahferom district was honey (71%), bee colony (35%), bee wax (3%) in the order of their importance. About 20, 97 and 95% of the beekeepers were sale their honey products in highland, midland and lowland areas, respectively. Honey production and sale was higher in midland and lowland than that of highland. Whereas, colony swarming and sale of bee colony was more pronounced in highland areas. Honey is considered as cash crop and thus almost all the beekeepers sale honey to fetch money. The beekeepers produce honey with different colors, white (71%), *sergen* (71%) and red (53%). *Sergen* is referring to a combination of red and white. They sale honey at farm gate (71%) and local market (70%) carrying the product by themselves.

Producers grade their honey for sale based on personal evaluation, but there are no given standards for quality differentiation. Colour determines the utilization of honey and market price. The price of honey varies with colour. The average price of white honey at market place per kilogram was 1008.8 ETB with a minimum of 1000 and a maximum of 1200 ETB. It was an average of 941.6 ETB with a minimum of 700 and a maximum of 1200 ETB at farm gate. The average price of *sergen* honey at market place per kilogram was 839 ETB with a minimum of 650 and a maximum of 1000 ETB and an average of 784.1ETB with a minimum of 600 and a maximum of 1000 ETB at farm gate. Likewise, the average price of red honey at market place per kilogram was 669.5 ETB with a minimum of 500 and a maximum of 1000 ETB and an average of 617.1 ETB with a minimum of 400 and a maximum of 800 ETB at farm gate level (Table 16). This shows that the price of honey soon after harvesting season is bigger in market places than farm gates. White honey is more expensive followed by *sergen* honey and red honey in descending order. The fact was true in all ecological zones.

Table 16: Price of honey at different market place and at harvesting in the study area (2023)

Variables		Agro-ecology				
		Highland	Midland	Lowland	Overall	P-value
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	
Number of honeybee colonies sale annually		5.13±1.77	0.33±1.81	0.02±0.13	1.8±2.76	0.00
Price per colony		3091.7±308.2	153.3±832.7	75±580.95	1106.7±1534	0.00
Total income from colony sale (ETB/year)		15950±6001	1533.3±8326.9	75±580.95	5852.8±9298	0.00
Crude bees wax from traditional hive kg/ hive		0.008±0.07	0.18±0.91	0.03±0.18	0.075±0.54	0.16
Price of white honey at market place ETB/kg		1006.6±25	1015±159.8	1004±101	1008.8±125	0.89
Price of white honey at farm gate ETB/kg		987.5±50	953.5±115.4	917±75.8	941.6±95.9	0.01
Price of red honey at market place ETB/kg		650±62.68	690.0±105.3	655±52.5	669.5±81.9	0.08
Price of red honey at farm gate ETB/kg		636.7±66.7	626.7±114.6	601±55.9	617.1±87.7	0.25
Price of *sergen* honey at market ETB/ kg)		825.0±40.8	849.1±88.67	835±91.1	839.9±85.3	0.52
Price of *sergen* honey at farm gate (ETB/kg)		806.3±40.3	793.8±109.2	768±75.4	784.1±89.48	0.19
Price of white honey ETB /kg at harvesting	Local	700±35	702±72	648±64	676±72	0.00
	Modern	694±32	732±73	656±47.9	701±69	0.001
Price of Red honey ETB /kg at harvesting	Local	417±41	370±27	371±36	374±34	0.005
	Modern	390±21	393±62	367±25	384±44	0.266
Price of *Sergen* honey ETB /kg at harvesting	Local	517±41	522±46	648±64	507±49	0.005
	Modern	515±24	537±59	491±49	517±54	0.025

SD = Standard deviation, N = Number of observations (N = 180)

The beekeepers determined the price of white honey at harvesting season with an average of 675.64 and 701.02 ETB/kg from traditional and frame hive, respectively. A minimum of 500 and a maximum of 900 ETB/kg was the selling price for honey from traditional and modern hives during harvesting season (Table 16).

The beekeepers determined the price of *sergen* honey at harvesting season with an average of 506.9 and 517.35 ETB/kg and a minimum of 350 and maximum of 600 and 700ETB/kg from traditional and modern hives, respectively during harvesting season (Table 16). Likewise, the average selling price of fresh honey was determined to be 373.66 ETB and 383.78 ETB/kg from traditional and modern hives, respectively.

The result implies that in the same manner the price of honey fluctuates with highest price in the dry season especially during the period after harvesting time (December to April) and wet season (July to August) and lowest price at honey harvesting time (September to November). The price of honey from modern hive was slightly higher in price and better preferable than traditional hive honey. The general marketing of honey in the area was more encouraging to beekeepers and beneficiaries. It was also understood that there were price variations according to the beekeepers' description based on quality and purity of honey (71%), season of the year (75%), colour and test of honey (71%) and based on market distance (39%).

The result is in line with the report of Tizazu *(*2018*)* who observed that honey price was low during the peak production season and high during the slack season and also honey with white colour and good tastes get better price in Sayo district, Western Oromia, Ethiopia. According to the opinion obtained through this study, honey with white colour and clear honey is highly preferred on the market, whereas red colour is regarded as low quality for which not preferred by consumers and traders. Similar finding was reported by Etenesh (2016) who revealed that the colour of honey in the study area was red yellow and somewhat white. She added that the yellow colour honey is most preferred than red.

Figure 13: Some of the crude beeswax processing beekeepers in the study area

4.3.3. Honeybee Colony Reproductive Swarming

Reproductive swarming is the natural way in which honeybee colonies reproduce. That means some workers move from the colony with virgin or mated queens to a new place and cooperate to build their new nest. Swarming behavior gives an extension to the life of honeybee colonies where the mother colony can live for a long time and multiple swarms can result from it.

Reproductive swarming is a common phenomenon in honeybee colony in Ahferom district, especially in the highland areas. About 35% of the respondents replied that there was an incidence of reproductive swarming during the study period (2023). The mean reproductive swarming incidence per household was 1.47 colonies with maximum colonies 10 and 35% of the sample respondents have experience of catching incidental swarms. About 100%, 3% and 2% of the sampled beekeepers had experience of reproductive swarm catching in highland, midland and lowland, respectively and 35% at district level. This result agrees with report of Belie *(*2009*)* who recorded 86% experience in catching swarm for beekeepers in Burie district of Amhara region, Ethiopia.

From the total 180 respondents, occurrence of reproductive swarming was observed in highland (100% of the beekeepers), midland (3%) and lowland (2%) (Table17). This shows that bee colony swarming is more common in highland areas as compared to that of midland and lowland areas due to agro-ecological cold environment and management practice. The beekeepers use both traditional and modern frame hive for reproductive swarming purpose. Midlanders and lowlanders do not practice colony swarming in modern hive. Natural reproductive colony swarming is more common phenomena and advantageous to increase colony number (100%), for sale and get income (100%) and to replace non-productive colony (100%).

Table 17: Reproductive colony swarming in each agro-ecology of the study area

Reproductive swarming		Agro ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Colony swarming	Yes	60	100	2	3.30	1	1.70	63	35.0
	No	0	0	58	96.7	59	98.3	117	65.0
Type of hives best swarming	Traditional	54	90	2	3.30	1	1.70	57	31.7
	Modern	6	10	0	0.00	0	0	6	3.33
Frequency of swarming	Every year	39	65	0	0.00	1	1.7	40	22.2
	Twice a year	21	35	2	3.30	0	0.00	23	12.8
More frequently swarming months	September-October	22	36.7			1	1.70	23	12.8
	August-October	28	46.7	2	3.30	0	0	30	16.7
	August-September	10	16.7		0	0	0	10	5.60
Swarm catching experience		60	100	2	3.30	1	1.70	63	35.0
Advantage of colony swarming	To increase colony number	60	100	2	3.30	1	1.70	63	35.0
	To sale and get income	60	100	2	3.30	1	1.70	63	35.0
	To replace non-productive colony	60	100	2	3.30	1	1.70	63	35.0
Total number of colony swarmed (2023/24)		63 beekeepers						301colonies	

N= Number of observations

Regarding the frequency of swarming, it can occur every year (65%) and twice a year (35%) in highland (Table 17). Swarming was more common in traditional hives (90%) than modern hives (10%). The traditional hive is best swarming hive in the areas. This might be due to the small size of traditional beehives that induce overcrowding so that bee colonies are forced to issue reproductive swarm. The discussant beekeepers mentioned that removal of the successive queen cell swarms after catching the first one to three strong swarm leads to protect from colony weakness. Environmental temperature and the quality of the beehives from which it is constructed are listed to have an impact. The respondent beekeepers also mentioned that frequency of reproductive swarming depends on the availability of honeybee flower and season of the swarming occurrences. In contrast to absconding, swarming is more prominent from August to October with 47% and 17% in highland and overall, respectively (Table 17). A study by Addisu and Desalegn (2021) in south Wollo zone indicated that 93% of the respondents appreciated the existence of swarming and a small portion of swarming happen in modern hives (6%). The authors noted that the most frequent swarming was observed in traditional hives (91%).

The mean number of swarms per colony was 1.47±0.57, 0.07±0.36 and 0.02±0.13 in highland, midland and lowland areas, respectively. The overall mean was 0.52±0.78, 0.52±0.78 and 1.68±2.49 number of swarms per colony, colony selected for the next generation and number of swarms catch in the production year of 2023, respectively (Table 18). There is high significant difference ($p<0.00$) in reproductive colony swarming in the district.

Table 18: Reproductive swarming of honeybee colony in the study area (2023)

Agro-ecology	Number of swarms/colony	Number colony selected for the next generation	Number of swarms caught in 2023 year
	Mean±SD	Mean± SD	Mean± SD
Highland	1.47±0.57	1.47±0.57	4.65±1.35
Midland	0.07±0.36	0.07±0.36	0.33±1.81
Lowland	0.02±0.13	0.02±0.13	0.05±0.39
Overall	0.52±0.78	0.52±0.78	1.68±2.49
P-value	0.000	0.000	0.000

N = Number of observations (N = 180), SD = Standard Deviation

The average reproductive swarm caught in the production year was higher in highland as compared to the other locations. In favour of this study, Guesh *et al.*, (2018) reported that the mean reproductive swarming incidence per colony was 8.77, 9.12 and 8.64 in highland, midland and lowland, respectively and insignificant difference ($p>0.05$) was observed. However, the average number of incidental swarms caught by the respondents was 1.44, 1.71 and 1.90 in highland, midland and lowland, respectively. The result is also similar with Belie *(*2009*)* who reported about 54.7% of the respondents replied that there was an incidence of reproductive swarming during the study year (2008/9) the mean reproductive swarming incidence per household was 0.41 colonies for local hives and 1.55 colonies for frame hives in Burie district of Amhara region, Ethiopia.

There are different techniques to control reproductive swarming of colonies. Beekeepers use many ways of controlling reproductive swarming including queen cell removal before the queen hatch out, use large volume of hive, supering hive and harvesting or cut combs. Reproductive colony swarming is used as main income source in highland areas. The beekeepers in highland areas explained that overcrowding of honeybee colonies, use of very small hives and cold condition are the major cause for the incidence of reproductive swarming. This is in good agreement with the findings of Alemayehu *(*2021) in Arba Minch Zuria district, southern Ethiopia.

Figure 14: Reproductive swarming in the district area

4.3.3.1. Honeybee Colony Marketing

Honeybee colony marketing is becoming known practice in Ahferom district of Tigray region in which colonies are carried to Enticho honeybee market place and in their community (at home). Due to its recently reproductive swarming exercise, about 35% of the sampled beekeepers had the experience of selling honeybee colonies and an average of 1.26±1.88 (75%) of the swarmed colonies are sold annually. The result indicates about 100%, 3% and 2% of the beekeepers in highland, midland and lowland areas have the experience of colony sales, respectively (Table 19). About 85% of the beekeepers bought a colony with 55% in highlands, 100% midlands and 100% lowlands.

Table 19: Different types of hive products in each agro-ecology of the study area

Types of hive products		Agro-ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
Colony sale		60	100	2	3	1	2	63	35.0
Colony buying		33	55	60	100	60	100	153	85.0
Collecting of crude bees wax	Yes	1	2	4	7	1	2	6	3.3
	No	59	98	56	93	59	98	174	96.7
Lack of knowledge		59	98	56	93	59	98	174	96.7
Lack of processing skill		59	98	56	93	59	98	174	96.7
Lack of processing material		54	90	56	93	59	98	169	93.9
Propolis collection- No		60	100	60	100	60	100	180	100.0
Honey sales		12	20	58	97	57	95	127	70.6
White honey		12	20	58	97	57	95	127	70.6
Red honey		12	20	42	70	42	70	96	53.3
Sergen honey		12	20	56	93	60	100	128	71.1
Honey sale at market place		12	20	58	97	57	95	127	70.6
Honey sale at farm gate		12	20	58	97	56	93	126	70.0

N= Number of observations

In comparison, beekeepers in the highland have more experience of colony sales from reproductive swarming practice than midland and lowland areas (almost none). On the contrast, colony purchase was higher in midlands and lowlands areas than that of highland areas. The current price of one bee colony ranged from 2500 to 4600 ETB with an average of 3251.6±436.8 ETB and the average income from colony sale was 5852.8 ETB/year per household.

Before ten years, the price of one honeybee colony ranged from 500 to 1,800 ETB with an average of 1245.69±305.97 (ETB) in Tigray region (Godifay, 2015). Currently, the selling price of a single honeybee colony is drastically increasing from time to time. The price of a well-established colony in a local hive ranged from 250-300 ETB before 2008 in Ahferom district (Adgaba, 2008*)*. This is due to the high demand of honeybee colonies in the study areas.

The selling price of one bee colony is drastically increasing from time to time. This fact attributed to increased trend of honeybee products demand both in beekeepers and non-beekeepers, newly engaged farmers and landless youth to beekeeping activities and increasing attention to the beekeeping sub-sector by the government and involving non-beekeepers through improved beekeeping practices. Honeybee colony selling depends on natural reproductive swarming besides introduction of colony multiplication technologies. Understanding about the current demand and price of bee colony, one can note that rearing and selling honeybee colony can be an advantageous opportunity and sole means of livelihood earnings income. Therefore, it is one of the intervention areas to enable and make specialize some of the best beekeepers at different places of the district to embark on such rewarding venture.

4.3.4. Colony Absconding Tendency and its Trends

Colony absconding was mentioned as one of the major problems in beekeeping production system in the study areas. About 92% of the beekeepers faced colony absconding and the corresponding values were 98%, 87% and 90% in highland, midland and lowland, respectively. More frequently and very serious absconding tendency was observed in traditional hive with 95%, 75% and 88% in highland, midland and lowland areas, while the values for modern hive were 28%, 48% and 37% in highland, midland and lowland, respectively. High absconding occurrence have been seen in traditional hive at highland areas because of the bee colonies set freely in the backyard area with no protective materials, so the bee colonies can attack easily by pests and predators and unwise application of agro-chemicals(pesticides and herbicides application).

Honeybee colony absconding occurrence in traditional hive showed increasing trends in consecutive years from an average number of honeybee colony per household 0.70±0.98 (2019) to 0.75±1.19 (2023) in highland. Likewise, an average of honeybee colony absconded increased from 0.2±0.51 (2019) to 0.38±2.48 (2023) in lowland, while an average number of 0.47±0.72 honeybee colony absconded with no increasing trends in midland (Figure 15). The most serious absconding occurrence trends of honeybee colony per household was observed in the consecutive years with an average of 6.52±5.18 in highland, 1.47±1.21 in midland and 1.58±1.28 in lowland areas respectively in 2021. This implied that the increasing trends of honeybee colony absconding occurrence trends in traditional hive were highly significant different ($p<0.00$) in the study area.

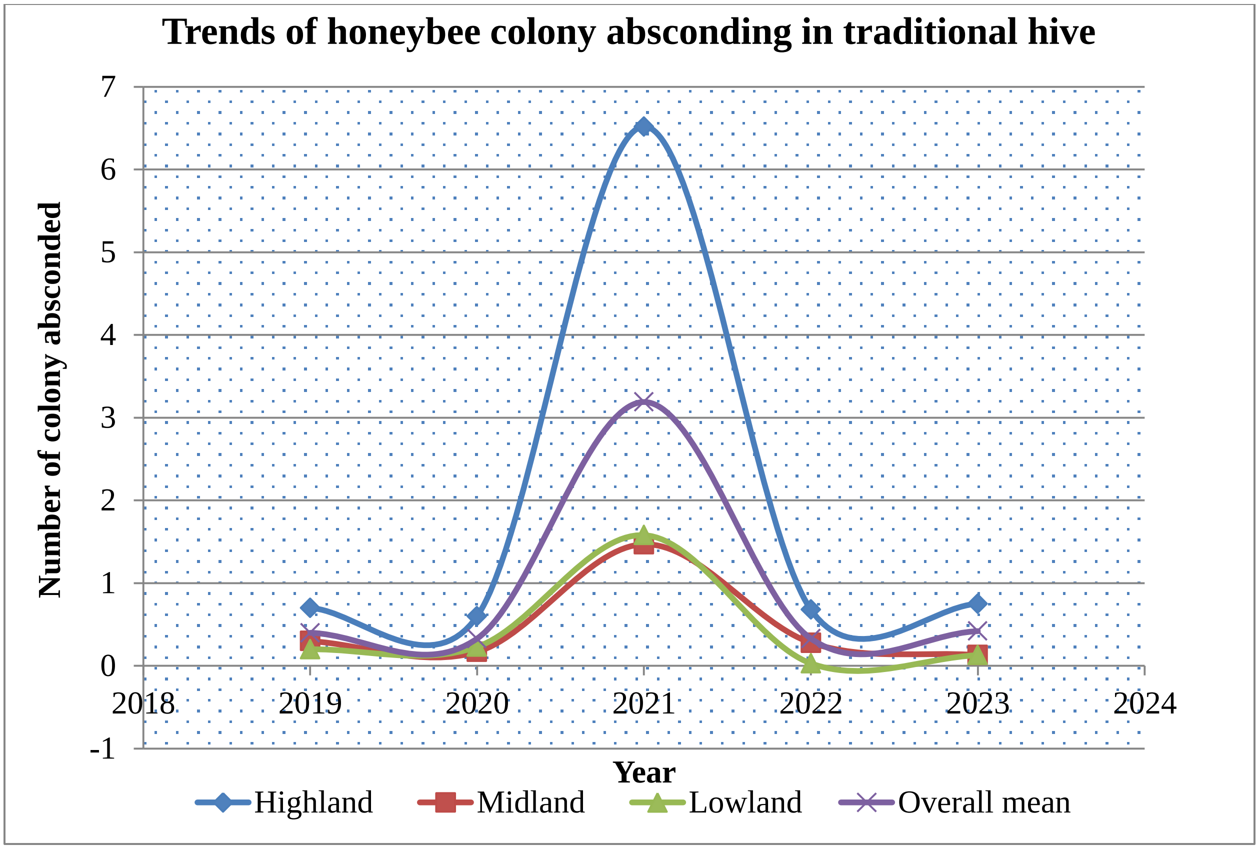

Figure 15: Trends of colony absconding in traditional hive in each agro-ecology

Absconding trends of honeybee colony number per household in modern hive showed an increasing trend in consecutive years from an average number of 0.17±0.91 (2019) to 0.03±0.26 (2022) in highland, whereas no absconding occurrence in 2023 and the mean number of honeybee colony absconded increased from 0.02±0.13 (2019) to 0.05±0.22 (2023) in midland and an average number of absconding colony increased from 0.07±0.31 (2020 E.C) to 0.15±066 (2023) in lowland, whereas no absconding occurrence happened in 2019 (Figure 16). The most serious absconding occurrence trends of honeybee colony per household was observed in the consecutive years with an average of 0.55±0.96 in highland, 1.15±1.70 in midland and 0.58±0.98 in lowland areas in 2021 (Figure 16). The result implies that the increasing trends of honeybee colony absconding occurrence in modern hive were insignificant different ($p>0.05$) in the study area.

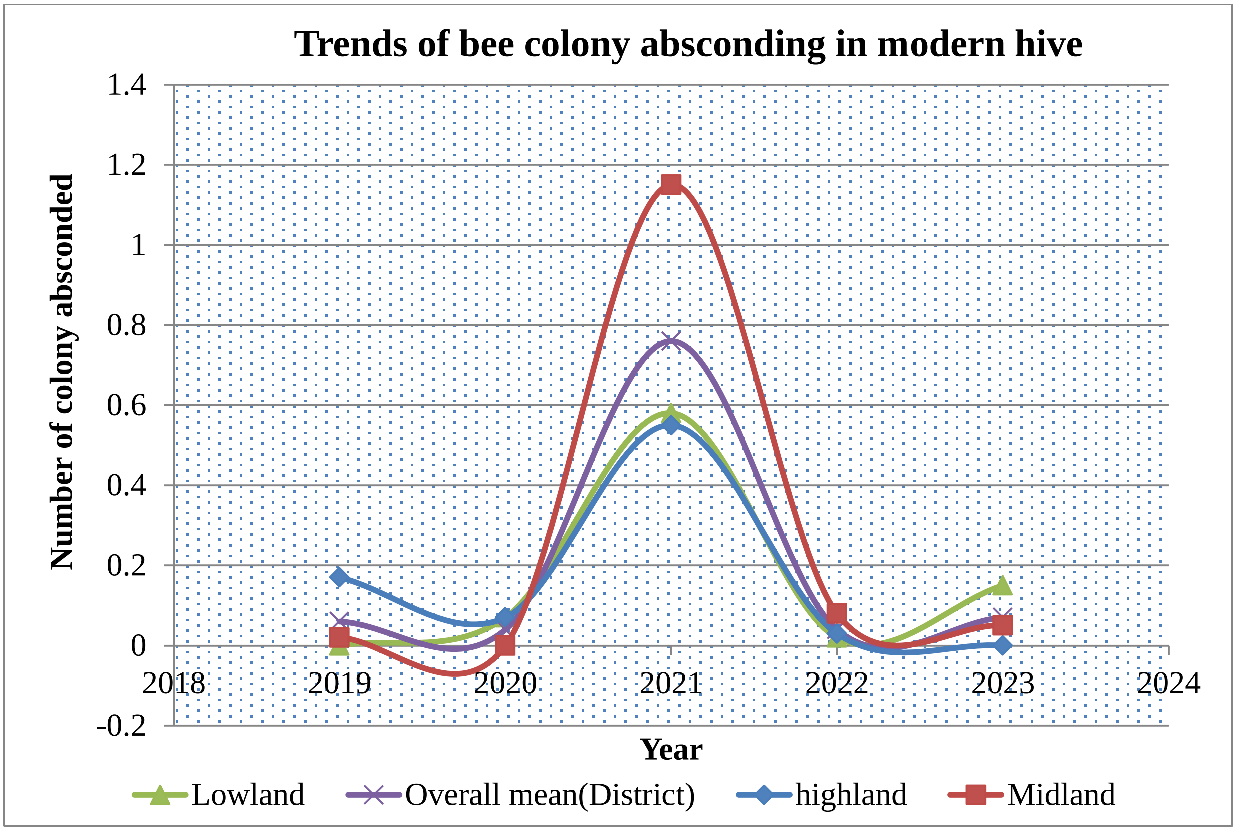

Figure 16: Trends of colony absconding in modern hive in each agro-ecology

Generally, the mean number of bee colony absconded from 2019 to 2023 in traditional hives was 1.85±1.90, 0.47±0.72 and 0.48±0.98 in highland, midland and lowland areas, respectively. In modern hives, the corresponding value was 0.164±0.498, 0.26±0.494 and 0.164±0.416 in highland, midland and lowland areas, respectively per beekeeper within the last five years (2019-2023). This finding agrees with the result of Belie (2009) who reported that about 2.6 mean bee colonies absconded per beekeeper at the Burie district of Amhara Region.

Absconding trends of honeybee colony number per household showed an increasing trend in consecutive years from an average number of colonies 0.41 to 4.63 in traditional hive and 0.24 to 3.63 in modern hive between year 2019 and 2023 (Figure 16). Within the last five years, a total of 842 traditional and 172 frame beehives were absconded in the district. The frequency of absconding was higher in traditional hives as compared with modern hives (Figure 17).

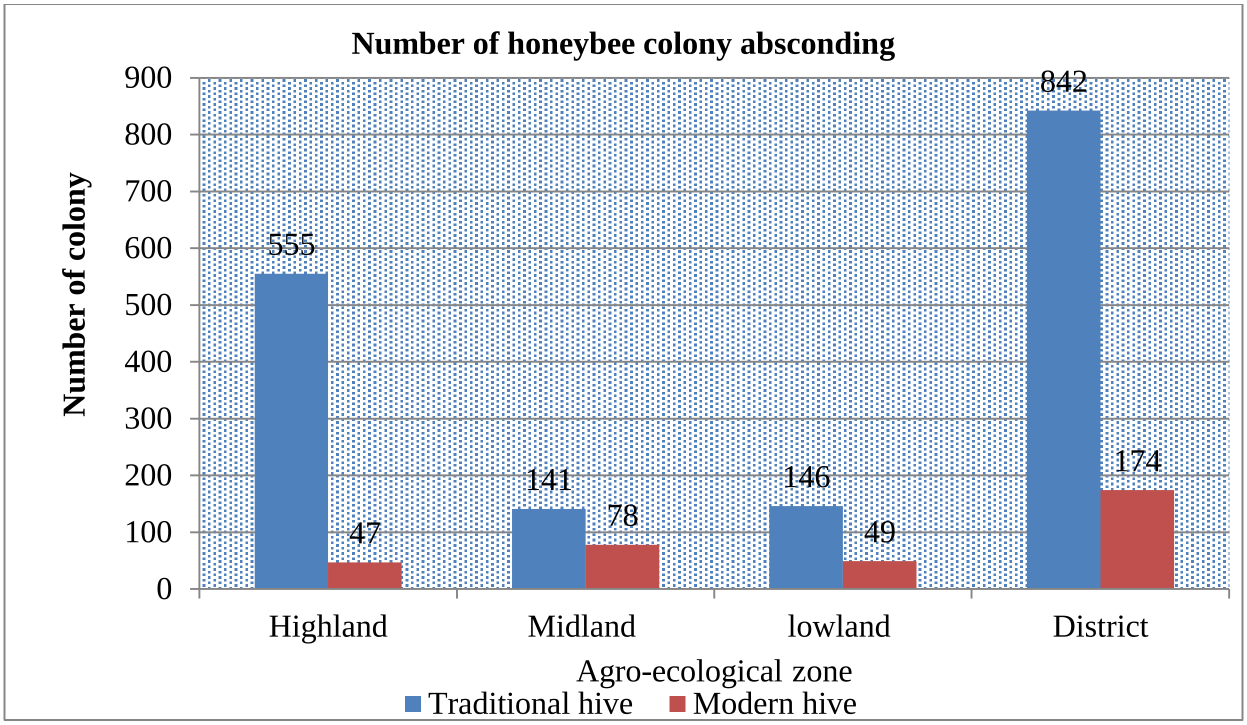

Figure 17: Colony absconding in traditional and modern hive in each agro-ecology (2019-2023)

An average number of modern bee hive enumerated during survey in beekeepers apiary was 0.64 with honeybee colonies and 0.96 without bees due to colony absconding at different time for different reasons. The average number of traditional bee hive colonized was 4.12, whereas 4.68 hive without honeybee colony. The frequency of absconding was highly significant different ($p<0.001$) in traditional beehives but not significantly different ($p<0.05$) in frame hives. There was a financial loss due to absconding of honeybees from modern and traditional hives. A total of 842 traditional and 172 frame beehives absconded honeybee colonies represented a minimum loss of about 2,974,099 ETB and 650,700.65 ETB, respectively from the sale of bee colonies. From the total absconded honeybee colonies (1014 empty beehives), it could be possible to earn 4,082, 232 ETB from the sale of honey. This result is similar with the findings of Guesh *et al.*, (2018) who reported that there was a financial loss due to absconding of honeybees from frame and traditional hives in different agro-ecological zones of Tigray region, Northern Ethiopia. A total of 441 traditional and 854 frame beehives without honeybee colonies represented a minimum loss of about 661,500 ETB and 3,996,720 ETB, respectively and from the existing total 1295 empty beehives; it would be possible to earn 4,658,220 from the sale of honey at different agro-ecological zones of Tigray region, Northern Ethiopia.

From the total absconded colonies, traditional hives were more likely absconding (92%) due to the reasons of inconveniency for management and being easily attacked by different factors. The absconded bees from frame hives was 8% and this might be due to skill development made on frame hives concerning its seasonal management and pest control to minimize absconding.

About 62% of the beekeepers reported absconding of their honeybee colonies with the absconding frequency occurred (73%, 63%, 62%) in highland, (32%, 78%, 72%) in midland and (33%, 67%, 78%) in lowland areas in December-February, March-May and June-August, respectively (Appendix Table 35). This result agrees with the findings of Tizazu (2018) in which about 83% of the respondents reported absconding of their honeybee colonies with the absconding frequency occurred 37%, 26%, 13%, 8% and 16% in March to May, September to November, December to February, June to August and no response or they do not know about absconding, respectively in Sayo district, eastern Oromia, Ethiopia.

This was further explained that absconding has been a major problem in traditional hives because of the fact that the hives are not convenient for internal inspection and also in frame hives because of the lack of skill in frame hive colony management. Of course, this has been also a self-explanatory problem happening because the majority of the beekeepers are not inspecting their colonies frequently. This is also because most local beekeepers believed that opening colonies in any time of the year will increase absconding which needs to be changed. As a suggestion, beekeepers should have always followed their bee hives to know the colony problem and control it from bee enemies. Seasonal management such as feeding in dearth period, follow after transferring, reducing the space/super were essential for frame hives. Beekeepers within the study area tried to regulate absconding through different mechanisms to control bee colony absconding which includes queen wing clip, providing additional feeds, queen caging (made up of from grass, bamboo and hide), leaving honeycombs during harvesting, frequent inspection, cleaning and smoking the beehives with attractant materials.

Figure 18: Locally used queen cage in Ahferom District

4.3.4.1. Major Causes of Absconding

The major causes of absconding of honeybee colony was shortage of bee forage, pests and predators, drought that can be manifested with rain fall distribution, pesticide and herbicide application and post war effect. The major causes of absconding of honeybee colony were due to post war effect 0.208 (177), shortage of bee forages 0.199 (169), pesticides and herbicide application 0.198 (168), pests and predators 0.196 (167) and drought 0.186 (158) in the order of their importance (Table 20).

Table 20: Causes of honeybee colony absconding across different agro-ecologies

Causes of absconding	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
War effect	0.221(60)	1	0.202(60)	1	0.203(57)	1	0.208(177)	1
Forage scarcity	0.20(55)	3	0.195(58)	2	0.21(56)	3	0.199(169)	2
Chemical	0.213(58)	2	0.192(57)	3	0.189(53)	5	0.198(168)	3
Pests and predators	0.195(53)	4	0.202(60)	1	0.192(54)	4	0.196(167)	4
Drought	0.165(45)	5	0.189(56)	4	0.203(57)	1	0.186(158)	5
Disease and parasites	0.003(1)	6	0.020(6)	5	0.014(4)	6	0.013(11)	6

The result agrees with other studies (Gidey and Kibrom, 2010; Kiros and Tsegay, 2017; Yirga *et al.*, 2012) who noted that shortage of bee forage was the major constraints and the pressing factors affecting beekeeping business. Absconding of bee was identified as the second most important problem and challenging factor for beekeeping sector (Haftu *et al.*, 2015).

The result indicated that pests and predators like birds, ants, spiders, wasps, small beetles, *Anbessa-Nhbi*, lizard, wax moth, honey badger, toads, snake and bee lice were the major causes of honeybee colony absconding. The finding agrees with the result of Firisa and Dejene (2016) and Godifey (2015) who reported that from the total 2624 honeybee colonies owned by the surveyed beekeepers, 1019 (38.8%) of them absconded due to wax moth, ant, honey badger and death head hawks in selected zones of Tigray region. This study showed that bee colony absconding prevails during the dearth period, especially from March to May and June to August. This agrees with the result of Guesh, *et al.* (2018) who observed prolonged dearth periods cause bee forage scarcity. In addition, the discussants have explained that colony absconding is happening at any time of the year regardless of the hive types because of continues colony disturbances from different factors at different agro-ecological zones of Tigray region, Northern Ethiopia.

4.3.4.2. Honeybee Pests and Predators of the Study Area

The beekeeping production system of the study area is faced a multitude of challenges. Pests and predators are recognized as major ones. Pests endanger honeybee life and their product and lead the colonies to abscond or die. The current study shows that 88%, 100% and 90% of the sampled beekeepers in highland, midland and lowland areas were encountered problem of pest and predators, respectively. Respondents listed out pests and predators as important factor in irritating honeybees and their products.

After having identified the major pests, beekeepers were requested to rank them in order of their importance and the result indicated that birds 0.132(162), ants 0.127(156), spiders 0.109(134), wasps 0.108(133), small beetles 0.102(125), *Anbessa-Nhbi* 0.100(123), lizard 0.096(118), wax moth 0.087(105), honey badger 0.064(78), toads 0.032(39), snake 0.027(33) and bee lice 0.015(19) were identified as the most harmful pests in order of decreasing importance in the district (Table 21).

Table 21: Major pests and predators across agro-ecologies zones of the study areas

Major pests and predators	Agro ecology							
	Highland		Midland		Lowland		Overall	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Birds	0.181(60)	1	0.126(53)	2	0.103(49)	4	0.132(162)	1
Ants	0.13(44)	2	0.124(52)	3	0.126(60)	1	0.127(156)	2
Spiders	0.10(34)	6	0.117(49)	4	0.107(51)	2	0.109(134)	3
Wasps	0.11(35)	5	0.117(49)	4	0.103(49)	4	0.108(133)	4
Beetles	0.120(39)	4	0.100(42)	5	0.092(44)	5	0.102(125)	5
Anbessa Nhbi	0.121(40)	3	0.10(42)	5	0.086(41)	5	0.100(123)	6
Lizards	0.042(14)	9	0.131(55)	1	0.103(49)	4	0.096(118)	7
Wax moth	0.05(14)	8	0.091(38)	6	0.105(50)	3	0.087(105)	8
Honey badger	0.08(26)	7	0.053(22)	7	0.063(50)	6	0.064(78)	9
Toads	0.042(14)	9	0.01(4)	9	0.044(21)	8	0.032(39)	10
Snakes	0.003(1)	11	0.010(4)	9	0.059(28)	7	0.027(33)	11
Bee lice	0.02(6)	10	0.021(9)	8	0.008(4)	9	0.015(19)	12

The present result was in line with the findings of other scientific works (Adeday *et al.*, 2012; Belie, 2009; Chala *et al.*, 2013; Dabessa and Belay, 2015; Haftu *et al.*, 2015; Workneh, 2007) who reported the presence of pests and predators in Kilte-Awlaelo district of eastern Tigray, Bure district, Gomma district, Walmara district, central zone of Tigray and Atsbi-Wemberta, respectively.

The bee eater birds as a predator of the honeybees and difficult to control have been identified as a serious problem (challenge) for beekeeping in the area. This bee eating bird is sitting on a nearby branch of a tree or a fence and catches the worker bees at the hive entrance. Ant, the most important annoying insect, has been disturbing the colony which has forced a lot of colonies to abscond and be aggressive. Spiders cover through their webs on the ways of the bees is trapping the honeybees and prey on them. Wax moths are pests that cover the comb and destroy bees in the hive.

4.3.4.3. Indigenous Knowledge on Pests and Predators Controlling Mechanisms

Besides to identifications of pests and predators, beekeepers of Ahferom district have serious concern and have rich experience and various practices in controlling some of the honeybee pests. Traditionally, beekeepers practice different prevention mechanisms. These mechanisms might not be totally effective in alleviating these pests and predators. This needs research support to validate this prevention and controlling mechanisms to examine their effectiveness and negative impact on the bee. Similar finding was reported by Dabessa and Belay (2015) as beekeepers used different mechanisms to protect their honeybees from pests and predators in Walmara district of Oromia region. The indigenous knowledge of beekeepers used in preventing and controlling pests and predators is summarized in Table 22, but this result needs to be proven scientifically by researchers in order for the beekeepers to fully benefit from this apiculture subsector. These results are almost similar with the study of central Ethiopia (Workineh, 2011) and Keffa, Shako and Bench-Maji zone (Awraris et al., 2012).

Table 22: Major honeybee enemies and local control measures in the study areas

Pests and predators	Index	Rank	Local control measures of pests and predators
Birds	0.132(162)	1	Keeping their apiary in the morning, rising up something like cloths, festal, thin rope and spin around the hive and, Killing using 'wonchif, remove the constant place of the bird if it is around home and destroying the nest of birds Scaring the bee-eating birds from the area.
Ants	0.127(156)	2	Clean apiary, dusting fresh ash around the base of a hive stand, plastering hives stands with mud, applying malatin and hot water to their home nest/hole/, burning the ants with fire, destroying the original house of ant and killing the queen of ant found in the hole, plastering of thin rubber sheets and metals between the hive and hive stands, pour used engine oil around the hive stand and keeping weeds well away from the base of the hive stand.
Spiders	0.109(134)	3	Cleaning apiary site and hive entrance, removing the spider webs, putting ash around hive stand.
Wasps	0.108(133)	4	Cleaning apiary site, remove nests of wasps, narrow the hive entrance
Beetles	0.102(125)	5	Strengthening the colony or keep strong colonies, remove weak colonies, cleaning apiary site, narrowing the hive entrance, hand picking and kill, cover the opening of hive.
Anbessa Nhbi	0.100(123)	6	Killing, clothing the hive entrance at night time.
Lizard	0.096(118)	7	Use spin around and kill, lengthening hive stand and fixing smooth iron sheet on hive stand, entrance and cover, cleaning apiary site, coating legs of the hives with engine oil.
Wax moth	0.087(105)	8	Making the colonies to be strong, giving additional foods, reduce hive entrance, smoking/fumigating the hive with chomer, dung, fumigate with Olea Africana, rubbing with recommended plant materials like chomer, remove old comb, and strengthen the colony.
Honey badger	0.064(78)	9	Building strong fence and kill with the help of doges, Use of chasing dogs, use of "Metsawed" to kill, fencing the apiary site with strong fence, hanging hives with long hive standing.
Toads	0.032(39)	10	Killing, clean apiary, smoking
Snake	0.027(33)	11	Clean apiary, smoking with plant material and kill
Bee lice	0.015(19)	12	Smoking/fumigating the hive with materials like chomer, dung, grass, fumigate with Olea Africana making the colonies strong, giving additional food for weaken colonies.

4.4. Seasonal Honeybee Colony Management Practices

4.4.1. Frequency of Internal and External Honeybee Colony Inspection and Apiary Cleaning

The sampled respondents were interviewed to describe the frequency of inspecting their apiary and honeybee colonies. Accordingly, about 78%, 68% and 68% of the respondents replied that they take a look externally into the hives frequently in highland, midland and lowland areas, respectively. Likewise, about 18%, 32% and 27% of the respondents externally inspect their colonies some times in highland, midland and lowland areas, respectively and 3% and 5% of the respondents externally inspect rarely in highland and lowland, respectively.

Moreover, 35%, 38% and 15% of the respondents internally inspect their colonies frequently in highland, midland and lowland areas, respectively, and 40%, 48% and 55% of the respondents internally inspect some times in highland, midland and lowland areas, respectively, while 25%, 13% and 30% of the respondents internally inspect rarely in highland, midland and lowland areas, respectively (Table 23).

Table 23: External and internal bee hive inspection frequency of beekeepers

Frequency of inspection		Agro-ecology							
		Highland		Midland		Lowland		Overall	
		N	%	N	%	N	%	N	%
External inspection	Frequently	47	78.3	41	68.3	41	68.3	129	71.7
	Some times	11	18.3	19	31.7	16	26.7	46	25.6
	Rarely	2	3.3	0	0	3	5.0	5	2.8
Internal inspection	Frequently	21	35	23	38.3	9	15.0	53	29.4
	Some times	24	40	29	48.3	33	55.0	86	47.8
	Rarely	15	25	8	13.3	18	30.0	41	22.8
Apiary cleaning		60	100.	60	100	60	100	180	100

N = Number of Observation

The respondents inspect their colony and apiary externally (72%) and internally (29%) frequently. The result indicated that an external inspection of apiaries and honeybee colonies frequently done in highlands than in midland and lowland areas. For the frequency of external honeybee colony inspection, there was no significant difference ($p>0.05$) done across all agro-ecologies by the beekeepers. However, there was significant difference ($p<0.05$) in honeybee colony frequency of internal inspection undertaken at all agro-ecologies.

Discussants also claimed that bee will be disturbed if internal inspection is very frequent as did in external inspection. The result agrees with the findings of Guesh *et al*. (2018) who reported most beekeepers visit and inspect their beehives externally. However, internal hive inspection was limited at different agro-ecological zones of Tigray region, Northern Ethiopia. Similar finding was obtained by Teklu (2016) where farmers in Ethiopia do not commonly practice internal hive inspection; however, Yetimwork *et al*., (2015) reported that 53% of respondent beekeepers visit their honeybee colonies frequently in eastern zone of Tigray.

Though, inspection of hives and apiary is indispensable to safeguard honeybee colonies from different natural disasters and various hazards (pests, diseases and chemical poisoning), respondent beekeepers believe in that visiting the apiary and the hive externally or internally during rainy season causes diseases. For this reason, during rainy seasons the apiary is covered with grasses which can serve as a hiding place of pests of honeybees. Experiences show that external colony inspection can be done at any season, however, caution is required in what season and at what frequency the internal inspection should be conducted.

Beekeepers inspect colonies when colonies become weak and during honey harvesting seasons. This is apparently because of the absence of personal protective cloths and tools, fear of being stung, the risk of colony absconding and lack of awareness of the value of doing so. Moreover, almost all beekeepers in the study area perform external inspection and also clean their apiary to prevent ant and other insect pests from getting access to hives. In this regard, providing training to beekeeper farmers is essential.

4.4.2. Providing additional supplementary feed to honeybee colony

Honeybees face starvation due to lack of forage during dearth period and dry season. Beekeepers harvest honey, which the honeybees stored for themselves. As a result, honeybees face starvation due to lack of available feed. To overcome the problem, supplementary feed is required for the honeybees. In this study, it was found that 41% of the respondents provided supplementary feed and 59% of the respondents not provide supplementary feed but the supplemented feed amount was very small in different seasons. Respondents provided supplementary feed mainly during February to May (39%) followed by May to June (2%) with feed ingredients of sugar syrup (37%), *Shiro* (beans flour) (35%) and *Besso* (barley flour) (29%). The respondents in different agro-ecology vary in providing supplementary feed with 48.3%, 43.3% and 31.7% in highland, midland and lowland feeding their colony, respectively. Sugar syrup was used for feeding bees by the majority and followed by *Shiro* and *Besso* (Table 24).

Table 24: Locally available supplementary feed types for honeybee colony in the study area

Types of feed supplements	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	N	%	N	%	N	%	N	%
Honeybee feeding								
Yes	29	48.3	26	43.3	19	31.7	74	41.1
No	31	51.7	34	56.7	41	68.3	106	58.9
Besso kg/season	16	16	22	36.6	14	23.3	52	28.9
0.5 kg	4	4		00	0	0	4	2.2
1 kg	5	5	2	3.3	5	8.3	12	6.7
2 kg	7	7	18	30.0	9	15.0	34	18.9
5 kg	0	0	2	3.3	0	0	2	1.1
***Shiro* kg/season**	24	40	24	40.0		25.0	63	35
0.50 kg	2	3.3	0	0	0	0	2	1.1
1.00 kg	6	10.0	6	10.0	2	3.3	14	7.8
1.50 kg	2	3.3	0	0	0	0	2	1.1
2.00 kg	13	21.7	16	26.7	13	21.7	42	23.3
4.00 kg	1	1.7	0	0	0	0	1	0.6
5 kg	0	0	2	3.3	0	0	2	1.1
Sugar syrup kg/season	25	41.7	24	40.0		30	67	37.2
0.50 kg	4	6.7	0	0	0	0	4	2.2
1.00 kg	11	18.3	11	18.3	10	16.7	32	17.8
2.00 kg	9	15.0	13	21.7	0	0	22	12.2
4 kg	0	0	0	0	8	13.3	8	4.4
5 kg	1	1.7	0	0	0	0	1	0.6
Colony feeding months								
February-May	28	46.7	24	40.0	19	31.7	71	39.4
May-June	1	1.7	2	3.3	0	0	3	1.7
July-August	0	0	0	0	0	0	0	0

N= Number of observations

This result is in line with the result of Kiros and Tsegay (2017) and Tesfa *et al.* (2013) in Eastern Tigray and other parts of Ethiopia, where commonly used supplementary feeds include sugar, roasted spiced pulses flour *(shiro)* and barely flour (*besso*). Beekeepers in the study area had an experience of feed supplementation during the shortage of bee forage. Most of the beekeepers supplement their honeybee colonies from locally available feed types to survive dearth periods. Other researcher (Guesh *et al*., 2018; Yetimwork *et al*., 2015) reported that majority of the beekeepers practice dry season supplementary honeybee feeding outside the hive using open locally available materials in different agro-ecological zones and eastern zone of Tigray region, Northern Ethiopia, respectively.

Supplementary feeding was not common practiced by majority of the respondents in the district areas, but some of them provide supplementary feed during dry season (February to May) when there is shortage of natural forage for the bees. Feed supplementation to bee colonies was relatively better in highlands as compared to midlands and lowlands. Shortage of bee forage causes ~~the~~ honeybee colony to abscond to areas where resources are available for their survival. In addition to supplementary feeding to mitigate the shortage of feed for their bee colonies, planting bee forages around their apiary and leaving some amount of honey unharvest are also required to prevent absconding as well as to get the intended honey yield.

4.4.3. Honeybee colony major seasonal activities

Reproductive swarming, absconding and brood rearing are a common phenomenon in honeybee colonies life cycle. Honeybees perform their normal activities based on seasons, normally during honey flow and dearth period seasons. The beekeepers replied that there was an incidence of major brood rearing in the months of March-May (83%), June-August (100%) and September-November (100%). Accordingly, the beekeepers perceived that there is an incidence of brooding season in the months of September to November (100%), March to May (97%) and June to August (100%) in highland, September to November (100%), March to May (100%) and June to August (100%) in midland and September to November (100%), March to May (53%) and June to August (100%) in lowland areas (Table 25).

Table 25: Seasonal activities of honeybee colonies of the study area

Seasonal activities of honeybees		Agro-ecology								
		Highland		Midland		Lowland		Overall		P-value
		N	%	N	%	N	%	N	%	
Colony absconding season	December-February	44	73	19	32	20	33	83	46	0.00
	March-May	38	63	47	78	40	67	125	69	0.12
	June-August	37	62	43	72	47	78	127	71	0.12
Dearth period season	December-February	40	67	23	38	36	60	99	55	0.01
	March-May	52	87	58	97	47	78	157	87	.010
	June-August	18	30	28	47	51	85	97	54	0.00
Honey harvesting time	September-November	17	28	58	96	60	100	135	75	0.00
	March-May	3	5	4	7	2	3	9	5	0.71
	June-August	10	17	56	93	37	62	103	57	0.00
Honey flow season	September-November	60	100	60	100	60	100	180	100	0.00
	March-May	3	5.0	4	6.7	2	3.3	9	5	0.71
	June-August	60	100	60	100	60	100	180	100	0.00
Colony swarming season	September-November	60	100	3	5	1	2	64	36	0.00
	March-May	58	97	3	5	0	0	61	34	0.00
	June-August	60	100	3	5	0	0	63	35	0.00
Broad rearing seasons	September-November	60	100	60	100	60	100	180	100	0.00
	March-May	58	97	60	100	32	53	150	83	0.00
	June-August	60	100	60	100	60	100	180	100	0.00

N = Number of observations

The results indicated that September to October (100%), March to May (97%) and June to August (100%) are the main months when colony swarming occurs due to availability of pollen, vegetation coverage and character behavior of bees in highlands. November, December, January and February are months in which there is no record of incidence, whereas in midland 5% in months of September to October, March to May and June to August and lowland 2% September to October (Table 25). The result indicates almost no incidence of reproductive swarming in midland and lowland areas.

Honeybee colonies can abandon their hives at any season of the year for different reasons. The beekeepers indicate that December to February (73%), March to May (63%) and June to August (62%) in highland, December to February (32%), March to May (78%) and June to August (72%) in midland and December to February (33%), March to May (67%) and June to August (78%) in lowland mainly occur colony absconding months in their locality (Table 25). As indicated by the beekeepers, incidence of abscond were low in the months of December to February except in highland areas (this indicates due to colony swarm splitting) the colony becomes weak. According to beekeepers, the peak dearth periods of the year are dry season period (December to February and March to May) as there is no flowering plant as a source of pollen and nectar. Likewise, during rainy season (June to August) as the pollen of the flowering plants diluted and the nectar washed by the rain and denoted as dearth period and agro-chemical applications.

Similarly, high availability of honeybee plants, from June to December, was recorded. September to November is regarded as the main honey harvesting period of the year as this period is the main flowering season of the year; while, June-August is regarded as the second honey flow season/harvesting period of the year. Dearth period of honeybees occur between January and June (Figure 18).

The result agrees with Guesh *et al.* (2018) who stated that an incidence of major brood rearing occur in the months of May (26%), July (99%), August (99%), September (100%) and October (63%) in different agro ecological zones zone of Tigray region. September (99%), August (92%), July (33%) and October (21%) are the main months for colony swarming, while November, December, January, February, March, April and May are months no record of incidence. March (50%), April (54%), May (63%) and June (59%) are considered as the first four main colony absconding months. March to May, June to July are peak dearth periods while September to November regarded as the main honey harvesting period of the year and June regarded as the second harvesting period of the year. In agreement with this study, Tesfa *et al*., (2013) reported that months of October, November and December are regarded as the main honey flow season and harvesting period of the year as this period is the main flowering season of the year in western Amhara, Ethiopia.

4.5. Major Honey Bee Flora and Flora Calendar

About 36 major honey bee floras are identified by the beekeepers in the district (Table 26). These plants are classified on to trees, shrubs and herbs. Beekeepers indicated that the flowering calendar of each bee flora annually. In addition, based on their experience and indigenous knowledge, beekeepers identified six major poisonous bee floras. The most common honeybee floras available were *Kelamitos* (*Eucalyptus globulus), Chiendog* (*Otostegia integrifolia), Sasa* (*Combretum collinum), Hohot* (*Rumex nervosus), Awhi* (*Cordia africana), Girbea* (*Hypoestes forskaolii), Qolkal* (*Euphorbia abyssinica), Ere* (*Oleo berhana), Geisho* (*Rhamnus prinoides L.) and Gelgelemeskel (Bidens Macroptera) in highland and Kelamitos* (*Eucalyptus globulus), Awhi* (*Cordia africana), Momona* (*Acacia albida), Tebeb* (*Becium grandiflorum), Kliow* (*Euclea schimperi), Girbea* (*Hypoestes forskaolii), Chae* (*Vachellia abyssinica), Lahay* (*Acacia spp.), Hohot* (*Rumex nervosus), Tambuk* (*Croton macrostachyus), Seraw* (*Acacia etbaica), Qolkal* (*Euphorbia abyssinica) and Tahses (Dodonea angustifolia) in midland and Chigeno (Albizia amara), Geba* (*Ziziphus spina christi), Ala (Acacia tortilis), Seraw* (*Acacia etbaica), Weyba* (*Terminalia brownie), Tahses* (*Dodonea angustifolia) and Girbea* (*Hypoestes forskaolii) in lowland areas.*

The beekeepers perceived that feeding or foraging habits of bee from different trees, shrubs and herbs can lead to changes in the colour, taste, and aroma of the product (honey). Accordingly, almost all beekeepers indicated that honeybee flora such as *Eucalyptus globulus* and *Becium grandiflorum* produce white honey. Besides, honey produced from all bee floras has sweet taste except honey from *Eucalyptus globulus* and *Euphorbia abyssinica* that had a bitter taste. The result of this study coincided with the result of previous studies (Haftom *et al*., 2013; Yetimwork *et al*., 2015) who reported that beekeepers identified about 37 species of bee forages in eastern Tigray. This result is in agreement with Yetimwork *et al*. (2015) who reported that about 44% of the beekeepers identified plants like *Akacha* (*Acacia saligna*), *qnchb* (*Euphorbia species*); *limo* or false neem (*Melia azedarach)* and neem (*Azadirachta indica)* are poisons to the bees in eastern zone Tigray. Chala *et al*., (2012) noted that nectar or pollen of poisonous plants are toxic to the bees themselves, and those in which the honey produced from their nectar are toxic to humans in Gomma district of Jimma zone South west Ethiopia. The flowering time of bee forages may differ from one place to another due to variation in climate, topography of the areas.

Table 26: Major bee forages and flowering seasons in the study area

Scientific name	Local name (Tigrigna)	Plant types	Flowering season
Eucalyptus globulus	Kelamitos	Tree	Year round
Euclea schimperi	Kliow	Shrub	June-July
Schinus molle L.	Tkurberbere	Tree	Year round
Cordia africana	Awhi	Tree	November- December
Croton macrostachyus	Tambuk	Tree	October-November
Parkinsonia aculeate L.	Shewit hagay	Tree	Year round
Acacia spp.	Lahay	Tree	September- November
Acacia albida	Momona	Tree	February- March
Opuntia ficus indica	Beles	Shrub	March-May
Euphorbia abyssinica	Qolkal	Tree	September-November, February- May
Becium grandiflorum	Tebeb	Shrub	June- September
Hypoestes forskaolii	Girbea	Shrub	September- November
Rumex nervosus	Hohot	Shrub	November-December, March-May
Vachellia abyssinica	Chae	Tree	February-May
Ziziphus spina christi,	Geba	Tree	December- February
Acacia etbaica	Seraw	Tree	May-June, October- November
Mangifera indica L.	Mango	Tree	September-November
Persea Americana	Avocado	Tree	September-November
Psidium guajava	Zeythun	Tree	Whole year
Bidens macroptera	Gelgelemeskel	Herb	September
Oleo berhana	Ere	Shrub	October-November, February- March
Rhamnus prinoides L.	Geisho	Tree	July- August, March- April
Otostegia integrifolia	Chiendog	Shrub	February-May
Combretum collinum	Sasa	Shrub	February- April
Carduus nyassanus	Dander	Herb	October- November, March- May
Dodonea angustifolia	Tahses	shrub	March-June
Balanites aegyptiaca	Mekie	Tree	March-June
Albizia amara	Chigeno	Tree	March-June
Acacia tortilis	Ala	Tree	March-June
Terminalia brownie	Weyba	Tree	March-June
**Parthenium hysterophorus*	*Knche	Herb	September
**Foeniculum vulgare*	*Brbra	Shrub	Whole year
**Azadirachta indica*	*Nim	Tree	February- March
**Calpurnia aurea*	*Htsawts	Shrub	January- February
**Acacia Saligna*	*Akacha	Tree	January
**Solanum spp L.*	*Engule	Shrub	November-October

* Represents poisonous trees and shrubs

Figure 19: Major honeybee floras at dry season

4.6. Indigenous Knowledge of Beekeepers

In Ahferom district, beekeepers have rich indigenous knowledge on hive management and utilization of hive products. According to the responses of the beekeepers, the indigenous knowledge used by the beekeepers include reproductive swarming, bee sting prevention, bee sting pain minimization, bee colony strengthen, bee products as local medicine, disease investigation. disease control, honey harvesting season, smoking material, controlling reproductive swarming, biological control of honeybee enemies, swarm catching, identification of adulterated honey and increasing shelf life of honey (Table 27). Some of these indigenous knowledges need to be supported by scientific evidences.

The result agrees with previous findings of Solomon (2009) and Belie (2009) who reported that beekeepers have deep indigenous knowledge of beekeeping opportunities in the highlands of Southeast and Burie district of Amhara region Ethiopia. Moreover, it requires scientific support from research, as indigenous knowledge of the beekeepers contributions to the beekeeping development of the area is important and has paramount importance to improve quantity and quality of honey as well as other hive products.

Table 27: Indigenous knowledge of beekeepers across each agro-ecology of the study area

Descriptions	Indigenous knowledge of beekeepers
Reproductive swarming	Fumigation with *chomer*, *Olea Africana* and other plant materials *like ma-arkoek* and flood collecting material *(gefefot whj)*, rubbing with *Chomer*, and smoking baited hive by swarm attractant materials. Put the swarmed colony queen in locally made queen cage to protect from incidence of absconding in the new hive colony establishment for 3 to 6 days.
Bee sting prevention	Protective materials, naked body, smear hand with honey, eat fresh honey before honey harvesting, smoking, spraying water and avoid smelling materials (perfume, lemon…), black cloth, rubbing with leafs of *Hohot*, *shambowaeta* and pea
Bee sting pain minimization	Removal of stinging apparatus, eating young brood, pollen and/or honey, ointment with fresh soil, honey, butter and washing with cold water at the sting area.
Bee colony strengthen	Providing supplementary feeding (sugar, flour syrup, pepper and barley flour), uniting of colony, add brood comb, adding worker bees to the weak colony from the strong colony, fumigating with *chomer*, *Olea Africana* and frequent cleaning and inspection.
Bee product as local medicine	Stomach ache when mix with coffee, inflammation, coughing, malaria, anthrax, tonsil, heart failed, source of energy, anti-vomiting (as a mixture of honey and coffee) and cattle diseases, anthrax, anti-snake bit, foot mouth disease, eye fumigation brood comb (*Gofaeta*), *Mengegna*, wound solidify, attrite, and the scraped hide hair reestablishment in animals.
Disease investigation	Visual observation, decrease of colony, mass death of honeybees, unusual buzz of bees, bad smell of brood, disability of flying and forging ability
disease control	Cleaning of apiary and hive inspection, no entering into apiary from June to September (fumigation at this time with dung causes disease), not transferring the diseased colony to new hives, removal of old brood and diseased colony, fumigation with chomer and *Olea Africana.*
Adulterated honey	Incomplete burning of honey when heated, unusual colour, bad aroma and test, not Granulated, rubbing the honey in the skin of your hand if pure honey it creates crystalized particles, not creating layers in its container (either liquid or solid)
Honey harvesting season	Observation of honey aroma, cluster of bees outside hive, opening hive, decrease foraging activities, increase internal sound of bees, death of drones, decrease stinging and insert stick to beehive to check for honey presence, observation at entrances for what resource the honeybees are collecting nectar or pollen.
Increase shelf life	Using plastic bucket, and glass materials and pot. gourd increases shelf life of honey and no change in taste.
Smoking material	Smoking/fumigating the hive with materials like *ma-arkak*, *chomer*, dung, grass, with *Olea Africana* and flood collecting materials (*gefefot whj*) as an attractant material for colony population/brooding and swarming.
Colony swarm controlling	Removing brood, Queen Cell removal before the queen hatch out, use large volume of hive, harvesting or cut combs, increase hive volume and supering hive.

4.7. Beekeepers Honeybee Colony Selection Criteria in Apiary Management and Colony Marketing

The beekeepers identified the major colony selection criteria used in selection of strong and weak colony in their apiary of beekeeping management and during buying new colony from the colony market and community beekeepers. Like other livestock classes, beekeepers in the study area set honeybee colony selection criteria and rank them in order of their significance of production performance based on characteristics of worker bee population, body colour and size, comb building direction, aggressiveness behaviour, honey production potential, colony age, pests and predators resistance, docile behavior, adaptability to the area, drought resistance, ability of foraging, disease resistance, absconding, and swarming tendency (Table 28).

Table 28: Honeybee colony selection criteria of the study area

Selection criteria	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Bee colony population	0.102(54)	1	0.116(60)	1	0.117(60)	1	0.111(174)	1
Body size and colour	0.088(47)	5	0.116(60)	1	0.117(60)	1	0.107(167)	2
Direction of comb build	0.081(43)	6	0.114(59)	2	0.111(57)	2	0.102(159)	3
Aggressiveness	0.096(51)	3	0.105(54)	4	0.094(48)	4	0.098(153)	4
Honey production	0.092(49)	4	0.101(52)	5	0.101(52)	3	0.098(153)	4
Colony age	0.064(34)	10	0.107(55)	3	0.117(60)	1	0.095(149)	5
Pests and predators resistance	0.100(53)	2	0.06(31)	7	0.088(45)	5	0.083(129)	6
Docile behavior	0.077(41)	7	0.048(25)	10	0.068(35)	6	0.065(101)	7
Adaptability	0.039(21)	12	0.091(47)	6	0.058(30)	7	0.063(98)	8
Drought resistance	0.075(40)	8	0.058(30)	8	0.041(21)	9	0.058(91)	9
Foraging ability	0.068(36)	9	0.052(27)	9	0.043(22)	8	0.054(85)	10
Disease resistance	0.038(20)	13	0.021(11)	11	0.008(4)	12	0.022(35)	11
Absconding	0.03(16)	14	0.004(2)	13	0.021(11)	10	0.019(29)	12

The population of worker bees in the colony, colour of bees and direction of comb building, aggressiveness behaviour, honey production potential, age of colony, pests and predator resistance, docile behavior, adaptability to the area, drought resistance were the first ten most important parameters, while the others: ability to forage, disease resistance, absconding, swarming and wax production of the colony were ranked lowest (Table 29). This was in good agreement with Buchler *et al*. (2013) who described that the worker bee population, aggressiveness and honey yield history were also recommended characteristics for selection from beekeepers around the world. Similarly, the direction of comb building can be changed by guidance by using foundation sheet in European box hives as evidenced by the study of Adgaba *et al*. (2012) in selected districts of South Wollo Zone, Amhara, Ethiopia.

The beekeepers recognized that honeybee colonies in traditional hive construct their combs in three directions (*Difeo*, *Gonityel/Seyaf* and *Sala*). From the recognized comb building directions of the traditional hive, *Sala* is the one where combs are built parallel to the length of the traditional hive/starting comb building from the small queen room up to back side opening and *Difeo* is vertical to the long side of the hive. *Gonityel* or *Seyaf* are built neither perpendicular nor corresponding to the length but inclined along the length by some angles to the width which is in agreement with Tilahun *et al*. (2016) in different agro-ecological zones of Tigray northern Ethiopia.

These characteristics were less frequently seen in European box hive where colonies are guided to construct combs along the frames on the foundation sheet. Beekeepers prefer honeybee colonies that construct their comb direction perpendicular to the length side which is *Difeo* in highland and midland, whereas in lowland areas beekeepers prefer parallel to the length of the traditional hive which is *Sala*. The beekeepers prefer comb building direction by its advantage that facilitates honey harvesting and keep colony without damage during harvesting, best preferable for colony marketing, identification of the ripe honey combs and occasional inspection is easier if bees construct their comb in parallel and perpendicular pattern along the length side of the hive.

Regardless of the questionable reliability of body colour as a selection parameter, beekeepers categorized the colour of honeybee colonies as black, mixed and red from observation of the body colour. Mixed coloured colonies are those that have some individual worker bees black and with reddish abdominal hair colour in one bee hive. Most of the beekeepers categorized the honeybees based on their body colour in the study area. Beekeepers also noted that productivity potential and adaptation of different coloured honeybees dependent on the geographical location.

The honeybee colony is classified as big, small and medium in body size. The small body sized bee colony is more preferred by the beekeepers in all locations.

Table 29: Honeybee colony selection criteria across each agro-ecology of the study area

Selection criteria	N	Rank	Description of beekeepers on honeybee colony selection criteria characterization parameter
Bee population	174	1	Highly populated bee colony is more preferred
Colour and size of body	167	2	Black coloured and small sized bee colonies more preferable than red and mixed colour bee colonies.
Comb building direction	159	3	There are three comb building directions (*Difeo*, *Gonityel/Seyaf* and *Sala*). *Difeo* is more preferred for its management, internal inspection, honey harvesting and safely protect worker bee colonies from damage during harvesting and to leave combs for drought season.
Aggressiveness	153	4	Aggressive behaviour is more preferable to protect outside enemy intruders and highly productive bee type.
Honey yield	153	4	During colony marketing number of combs constructed in the hive.
Colony age	149	5	The colony selected during management and colony buying should be new bee colony, new small pure and white combs should be available if the colony is small aged/new swarmed colony.
Pests and predator resistance	129	6	Black coloured bees, small sized, aggressive behaviour and highly populated the colony will be expected strongly resistant from pests and predators.
Docile behavior	101	7	If the colony is red and big in size, it is docile in behaviour and can easily attack by enemies.
Adaptability	98	8	Black aggressive from high land areas are more preferred
Drought resistance	91	9	It should be black coloured, small size and aggressive and highly populated colony
Ability to forage	85	10	Ability of foraging can be used as a selection criterion in apiary managed colony by observation in morning and afternoon activity.
Disease resistance	35	11	It should be black coloured, small size and aggressive and highly populated colony
Absconding	29	12	If the colony is weak in its population and black coloured comb is available, it can occur absconding

N = Number of observations

4.8. Agro-chemical Application and their Effects on Honeybee Colony

The use of different agro-chemicals or pesticides is an important and common practice in crop production to fight against most crop damaging pest populations and diseases to produce high quantity of food around the world. However, if they are not used properly (according to their prescription for time of application and dosage), they bring about very crucial damage to pollination fauna (the honeybees in our case), environment and human health. As a result, reduction in pollinating insect population, quantity and quality reduction in hive products and crop yield reduction are some of the associated risks encountered.

As a matter of fact, honeybees visit flowering plants in search of nectar, pollen or both and fly from one plant to another. In this process, the honeybees are foraging on flowering plants on which some agro-chemicals have been applied for different reasons. Moreover, indiscriminate use of pesticides and herbicides has negative effects on the environment and the life of all pollinating insects. Sometimes, the effects of these chemicals on human beings are observable from different points which have been understood also by the local beekeepers.

Teff (78%), wheat (47%) and sorghum (32%) are the major crops produced in the study areas and followed by pulses, millet, barley, vegetables, and fruits in the order of their availability. Regarding pesticides utilization, majority (96%) of the study participants responded that they use chemical pesticides at different levels (regularly or occasionally) for crop production. Of those farmers who use chemical pesticides, 149 (83%) indicated that they use it for insect pest control, 171 (95%) indicated that they use it for weed control and about 30 (17%) indicated that the use of malaria control spray by government.

The farmers use agrochemicals for different purposes. According to the respondents, agrochemicals are relatively widely used in the highland (100%), midland (100%) and lowland (95%) in (Table 36). The beekeepers were requested to mention presence of agro-chemicals that poison to honeybees in their locality. The main agricultural chemicals reported to be mostly used by the farmers for insecticides and herbicides that highly affect honeybee colonies in rainy ~~summer~~ season were carrate 5% ECs, rider 5% ECs, fast killer 5%ECs, farrate 5%ECs, tomda 5% ECs, Bravo 5% ECs, and focus 5% ECs insecticides in liquid form. The herbicides commonly used which were dangerous to honeybee colonies *Agro- 2, 4-D* (power-2,4-D, awra-2,4-D,sgem-2,4-D, amba-2,4-D) in liquid form and carway-20%, rochway-50%, arsen-75% and ambassador-75% packaged in flour form. The agrochemicals commonly used in irrigation were mancozeb, korajen, trigger, netivo, acter, profit and tilt. As the discussants mentioned, there is an increasing trend of these chemicals application in the study areas in the years of 2019-2023. These chemicals directly or indirectly affect the life of honeybees or honeybee's production. Most of the agrochemicals are supplied by Office of Agriculture and Rural Development (WoARD) and licensed venders are source of agrochemicals in the study areas.

All the beekeepers (100%) reported that their honeybee colonies were affected by indiscriminate application of these agrochemicals and about 27%, 100% and 100% of the respondents replied that honeybee colonies lost/abscond, dwindle and died, respectively due to agrochemicals in the study district (Table 30).

Table 30: Agro-chemicals, season of application and their effects on honeybee colony

Agro chemical application activities	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	N	%	N	%	N	%	N	%
Agro-chemicals application purpose	60	100	60	100	52	95	172	95.6
Crop pests control	59	98.3	60	100	30	50	149	82.8
Weeds control	59	98.3	60	100	52	86.7	171	95
Malaria control	0	0	0	0	30	50	30	16.7
Application months of agro-chemicals								
July to August	60	100	60	100	0	0	120	66.7
July to September	0	0	0	0	60	100	60	33.3
Agro-chemicals affect honeybee colony	60	100	60	100	60	100	180	100
Honeybee colonies lost due to chemicals	26	43.3	7	11.7	16	26.7	49	27.2
Honeybee colonies dwindled	60	100	60	100	60	100	180	100
Honeybee colonies died	60	100	60	100	60	100	180	100
Agro-2, 4-D, Rider, fast killer, Karrate, farrate, etc…	60	100	60	100	60	100	180	100

N = Number of observations

The average number of honeybee colonies lost due to agrochemicals was 1.7±2.65, 0.08±0.22 and 0.39± 0.804 colonies per households in highland, midland and lowland, respectively (Figure 20).

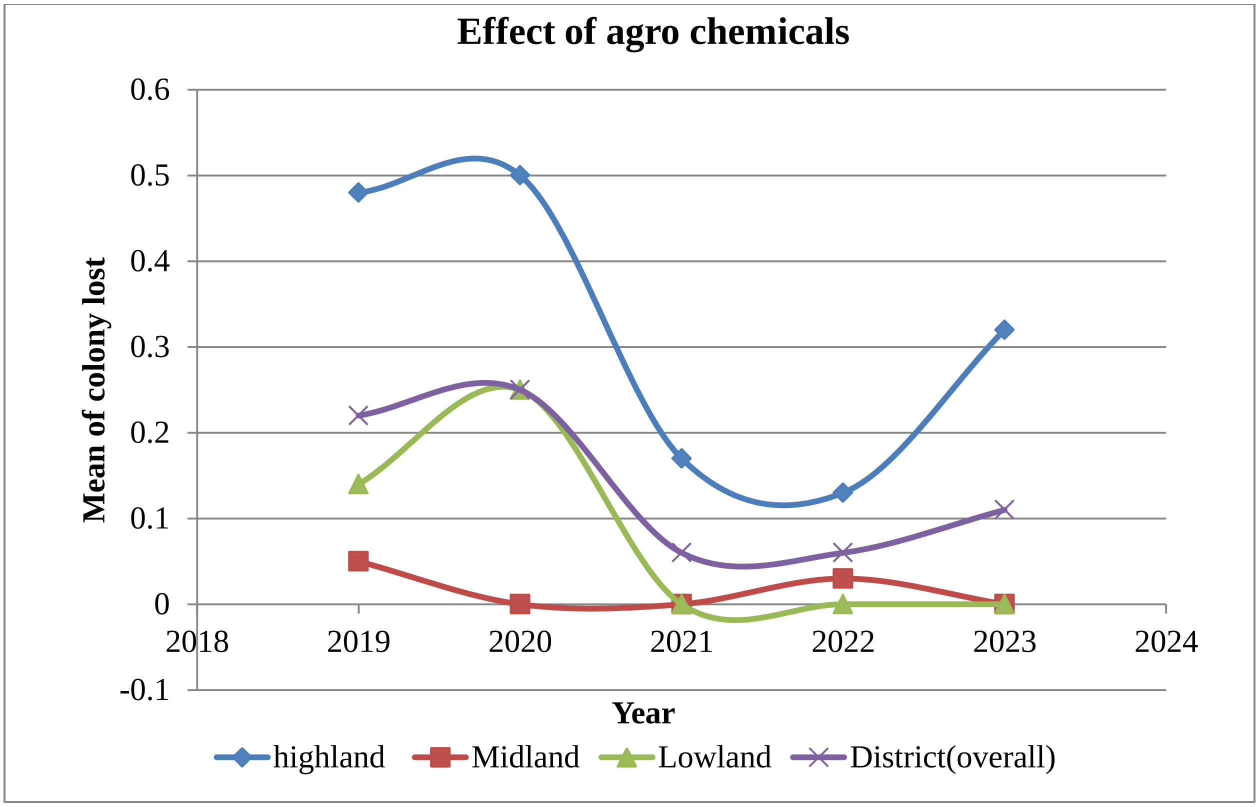

Figure 20: Trends of honeybee colony lost due to chemicals in the study area

The estimated price of honeybee colonies lost per household was 5167, 170 and 170 ETB in highland, midland and lowland, respectively during 2019-2023 (Table 31). The overall mean of honeybee colonies lost per household was 0.71±1.75 colonies and the estimated price of colony lost 2380 ETB due to chemicals effects. The respondents claimed that within the last five years, 102 honeybee colonies absconded in highland, 5 in midland and 24 in lowland areas. A total of 131 colonies lost with estimated price 475,089.84 ETB in the study area.

The average honey lost per household due to chemicals was 7.95, 44.82 and 87.97 kg in highland, midland and lowland, respectively and the estimated price of honey lost 7920, 46108 and 77756 ETB in highland, midland and lowland, respectively during the last five years (2019-2023). The average mean of honey lost due to chemicals effects was estimated to be 46.91 kg and the estimated price of honey lost 43928 ETB in the study area. A total of 8445 kg of honey lost with estimated price 7,917,050 ETB due to indiscriminate application of the above mentioned chemicals in the study area.

Table 31: Trends of agro-chemicals and their effects on honeybee colony in the study area (Mean±SD)

Items	Agro-ecology			
	Highland	Midland	Lowland	Overall
Honeybee colonies lost due to chemicals in (2019-2023)	1.57±0.50	1.88±0.32	1.73±0.448	1.73±0.447
2023	0.32±0.70	0.00±0.00	0.00±0.00	0.11±0.43
2022	0.13±0.50	0.03±0.18	0.00±0.00	0.06±0.31
2021	0.17±1.29	0.00±0.00	0.00±0.00	0.06±0.75
2020	0.50±0.89	0.00±0.00	0.25±0.54	0.25±0.64
2019	0.48±0.95	0.05±0.22	0.14±0.47	0.22±0.65
Honey lost due to chemicals in kg	7.95±20.43	44.82±37.88	87.97±115.95	46.91±78.21
Estimated price of honey lost in ETB	7920±20427.9	46108±44620	77755.83±112778	43928±76196
Colony lost due to chemical	1.70±2.65	0.08±0.22	0.39±0.804	0.72±1.75
Estimated price of colony lost in ETB	5166.7±7957.3	170±758.1	170±758.075	2379.6±5420

SD = Standard deviation

The current result is in good agreement with Adeday (2012) who reported that indiscriminate application of chemicals in the crop field caused substantial economic loss in the beekeeping sector in Wukro district Tigray region, Ethiopia. Honeybees exposed to agrochemicals in different ways. According to Fischer and Moriarty (2011), older worker bees forage outside the hive for pollen and nectar and thus are vulnerable to contact exposure to pesticides during foraging as well as dietary exposure during collection or ingestion of pollen and nectar. Workers also serve as a vector for bringing contaminants back to the hive. Young workers clean cells and attend brood, whereas middle aged workers do a variety of tasks mainly within the hive. All the young and middle-aged workers, queen and drone can have secondary exposure to pesticides through contaminated food brought back to the hive. Moreover, Amssalu *et al.*, (2012) noted that all commonly used agrochemicals except *Agro-2, 4-D Amin 720A*, were significantly toxic to Ethiopian honeybees when ingested with food.

Information gathered from respondents revealed that due to agrochemical application a number of honeybee colonies and honeybee production decreasing from time to time. The chemicals affect honeybees in two main ways, first by direct killing honeybees on field and when bring nectars and pollen sacking to the hive a number of broods and adult honeybees in the hive were died and the second way is by killing honeybee flowers on the field which otherwise used to serve as major food sources of honeybees. In short, these problems are technical, management and policy issues and can affect the production and productivity of beekeeping in the study area in particular and in Tigray region in general. Therefore, much focus has to be given to alleviate the effects of poisoning from agrochemicals to ensure productivity, quality and safety of beekeeping which is in agreement with Tizazu (2018) in Sayo district western Oromia, Ethiopia.

As an option to minimize risks of chemical misuse, some of the possible practical options which could be advised include use of chemicals late evening and/or early morning application, appropriate preparation of the chemicals according to their dosage and time of application, closing hive entrance for 1 or 2 days. In this case, respondent beekeepers have confirmed that even if they are applying the agro-chemicals in the early morning and late evening, the other crop farmers are applying the chemicals at any time of the day in general and around the mid-day in particular. Farmers who have no bee colony, they do not care for bees. Thus, at this point, the discussants suggested that all the stakeholders should participate and work together to discriminate misuse of agro-chemicals and encourage farmers to integrate the use of chemicals with beekeeping so that they could benefit from their business.

4.9. The Major Constraints and Opportunities of Beekeeping Production System

4.9.1. The Major Constraints of Beekeeping

In order to utilize the beekeeping sub sector, identifying the existing constraints and searching for solutions are of paramount importance. Beekeepers pointed out different problems affecting the beekeeping industry in their respective areas. The beekeepers in the study areas declared at least 14 major problems that hinder the development of beekeeping in all agro-ecologies of the district. Accordingly, the major problems affecting beekeeping development in the study areas were pesticides and herbicides application (0.124 ranking index), pests and predators (0.122), beekeeping equipment (0.119), shortage of bee forage (0.116), drought (0.115), absconding (0.111), death of colony (0.107), high wind (0.086), honeybee colony (0.045), high rainfall (0.019), shortage of water (0.017), high temperature (0.014), lack of bee hive (0.003) and diseases (0.001) ranked in order of their importance.

The importance of each constraint varies with locations. In highlands, the major constraints that hindered beekeeping development includes, poor supply of beekeeping equipment (0.131 ranking index), pesticides and herbicides (0.127), pests and predators (0.123), absconding (0.112), drought (0.109), shortage of bee forage (0.103), death of colony (0.092), and high wind (0.09) in order of their importance. Likewise, pesticides and herbicides (0.128), less supply of beekeeping equipment (0.128), shortage of bee forage (0.128), pests and predators (0.124), drought (0.124), death of colony (0.124), absconding (0.120) and high wind (0.066) were the available constraints in midland in descending order. In lowlands, the existing problems were identified as pesticides and herbicides (0.118), pests and predators (0.118), shortage of bee forage (0.118), drought (0.112), death of colony (0.112), absconding (0.102), shortage of beekeeping equipment (0.100), and high wind (0.100(51) in that order (Table 32).

Table 32: Major constraints of beekeeping production system of the study area

Major constraints	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Pesticides and herbicides	0.127(58)	2	0.128(60)	1	0.118(60)	1	0.124(178)	1
Pests and predators	0.123(57)	3	0.124(58)	2	0.118(60)	1	0.122(175)	2
Less beekeeping equipment	0.131(60)	1	0.128(60)	1	0.100(51)	4	0.119(171)	3
Shortage of bee forage	0.103(47)	6	0.128(60)	1	0.118(60)	1	0.116(167)	4
Drought	0.109(50)	5	0.124(58)	2	0.112(57)	2	0.115(165)	5
Absconding	0.112(51)	4	0.120(56)	3	0.102(52)	3	0.111(159)	6
Death of colony	0.092(42)	7	0.118(55)	4	0.112(57)	2	0.107(154)	7
High wind	0.09(41)	8	0.066(31)	5	0.100(51)	4	0.086(123)	8
Honeybee colony source	0.007(3)	12	0.051(24)	6	0.075(38)	5	0.045(65)	9
High rainfall	0.059(27)	9	0.00(0)	9	0.00(0)	8	0.019(27)	10
Shortage of water	0.035(16)	10	0.009(4)	7	0.008(4)	7	0.017(24)	11
High temperature	0.002(1)	13	0.00(0)	9	0.037(19)	6	0.014(20)	12
Shortage of bee hive	0.007(3)	11	0.002(1)	8	0.00(0)	8	0.003(4)	13
Diseases	0.002(1)	14	0.002(1)	8	0.00(0)	8	0.001(2)	14

The result is similar with findings of Yetmwerk *et al.* (2015) who reported that the most important constraints in their order of sequence were bee forage shortage, pests and predators, insufficient beekeeping equipment, absconding, inadequate honeybee colony, pesticides and herbicides, death of colony, water shortage, less honey storage materials, swarming and marketing in Kilte Awlaelo district, eastern zone of Tigray, Ethiopia.

As a result, prioritization of the problems was made to identify the most important constraints that hinder the development of beekeeping sub sector in the study area. Based on the result of this study, beekeepers much suffered from a number of difficulties and challenges that are antagonistic to the success desired in honey production. Major problems in beekeeping arise from bee characteristics or environmental factors that are beyond the control of the beekeepers. After having identified the major problems facing the beekeeping activities, beekeepers were requested to list their priority in order of importance. According to the response of the beekeepers and available information on major challenges of the beekeepers, the first most devastating constraint of honeybee production is unwise application of pesticides and herbicides (agro-chemicals) such as fungicides, pesticides, and herbicides. These days, it is becoming a social problem due to the conflict of interest between the beekeepers and non-beekeepers during its application.

Therefore, it deserves urgent action from the regional government to formulate policy and design legislations with regard to application of agricultural chemicals. Moreover, focus should be given to those chemicals which are not harmful to honeybees and the applications should not match with flowering seasons so as to minimize the poisoning effect on honeybees. In short, these problems are technical, management and policy issues and can affect the production and productivity of beekeeping in the areas. Therefore, much focus has to be given to alleviate the described constraints, to tap the maximum potential of the beekeeping industry. In this regard, it is time to develop beekeeping development strategy and policy (Table 32). The second which challenging beekeeping in the district area were honeybee enemies (pests and predators). The respondents mentioned that these constraints directly affect honeybees and hive products and have great impact on the economy of the beekeeping.

According to the respondent beekeepers, the third most constraints in the district area were deficit of beekeeping equipment/materials. Generally, moveable frame type hives are demanding more additional beekeeping equipment than traditional hive. However, majority of the beekeepers lack protective cloth, smoker, casting mould and honey extractors, without which improved beekeeping practices cannot be successful. Besides, apiculture equipment are expensive relative to the purchasing power of the beekeepers and knowledge gap, that is why the sample data indicate farmers hold a maximum of 60 empty modern hives with a mean of 3.87. Therefore, the adoption of improved beekeeping practices also relies on the supply of these basic inputs.

The respondents identified shortage of bee forage as the fourth major constraint followed by drought, absconding, and death of colony, high wind and lack of honeybee colony in the study areas. The results were from increasing problem of deforestation and over-gazing and lack of attention to introduce potential bee forage plants. The disappearance of woody vegetation (forests and woodlands) and overgrazing has nearly depleted the bee forage supply. The supply of natural bee forage is disappearing and as a consequence bee colonies are suffering, ultimately resulting in low yield. Therefore, in this regard, one has to provide supplementary feed to his/her colony, planting drought resistant bee forage species around the apiary and provide water to the colony. There is still huge potential to increase honey production and to improve the livelihood of the beekeepers in the district. Besides the existing natural base, government has recently put in its agenda the need to develop apiculture as one of the strategies to reduce poverty and to diversify national exports.

The current result is in agreement with the findings of Alemayehu (2021) who found that shortage of bee forage during dearth period, absconding pests and predators, risky application of agro-chemicals were among major constraints of beekeeping ranked in order of severity in Arba Minch Zuria district, Southern Ethiopia. Nebiyu and Messele (2013) also reported that the most important constraints of beekeeping were lack of beekeeping equipment's (1^{st}), shortage of bee colony (2^{nd}), high cost of modern hive (3^{rd}), pests and predators (4^{th}), lack of training (5^{th}), shortage of bee forage (6^{th}), shortage of water (7^{th}) and absconding (8^{th}) in the district Gamo Gofa Zone of southern Ethiopia.

4.9.2. Opportunities of Beekeeping

Despite all the constraints and challenges currently facing the beekeeping subsector, there are still enormous opportunities and potentials to boost honey production in the district. Based on the information obtained from key informants and focus group discussions as well as field observations, the major opportunities for beekeeping development are the availability of huge number of bee colonies which will give great opportunities for beekeepers who want to expand and produce more honey in the future. Currently, the government is giving stronger emphasis than ever before to the beekeeping sub sector to use it as a tool for poverty reduction and to diversify the national export. Accordingly, from the perception of the discussants, some of the opportunities associated with the study area and described by the respondent beekeepers are presented below:

4.9.2.1. Availability of Honeybee Floral Resources

As a matter of fact, the district at large and the different agro-ecologies in particular have been described by the respondents as a rich in floral resources. The diverse agro-ecologies and topography has been identified as one of the most important beekeeping potential areas in the district because of its floral resources. From the perception of the discussants, it can be said that the beekeeping farmers have understood the values of floral resources for increased honey production and survival rate of the honeybee colonies. Generally, identified honey bee forage species in the study area have been described and characterized in the above (Table 26).

4.9.2.2. Availability of Honeybee Resources

To start beekeeping, one person must find the colony by any means which is simple way to him/her. From all methods of catching swarm, obtaining from the environment by purchasing bee colony is more advantageous than the other methods because it does not acquire cost for other facilities and one can catch several colonies in one season. In the study area, most beekeepers start beekeeping by purchasing and catching the swarm from the environment and following by gift from their parents and also from their relatives and can easily buy from the community. This explains the environment has good access to honey bee resource and common practice of reproductive colony swarming.

4.9.2.3. Increasing Attention and Focus from the Government

To strengthen the apiculture sector and to produce the hive products and benefit from the activities of honey bees, the attention of government is very important. Nowadays, the government of the region focused on the apiculture sector by interconnection with natural resource conservation. In the study area, both government and non-government organizations undertake many activities in the form of training and helping the top beekeepers by providing them some modern bee hives.

4.9.2.4. Increasing Hive Products Demand

The increasing of hive product is depending on many reasons of management, floral resource, knowledge of honey flow period and so on. To increase the hive products, one beekeeper should update his/her knowledge by working many years with honey bee and have technology training from government and non-government organizations. In the study area, even though the result indicates that the production of honey decreased from year to year because of the war damage effects and other developed constraints; the demand of honeybee product is increasing fundamentally from year to year.

4.9.2.5. Employment Opportunity

Beekeeping activities are used as a main source of income in study areas with relatively small start-up costs and minimum land requirements. Beekeeping offers high opportunity for the landless and youth individuals to work in cooperatives on communal lands and area closures of the community.

4.9.2.6 Availability of Micro Finance Institution

There is an access of financial opportunities to start up beekeeping activities in a small scale with credit facility like Dedebit Micro Finance and Adeday Micro finance in the district area and farmers willingness to improve beekeeping practice in the areas. Different researchers had reported similar ideas (Workneh, 2006; Chala *et al.*, 2012; Shunkute *et al.*, 2012). The financial supports help the beekeepers to purchase modern hives, honeybee colonies, materials and other accessories.

4.10. Impact of Tigray war on beekeeping status of the study area

The beekeepers mentioned that before war government and non-government organizations put great attention on the beekeeping sector in the region to transform from traditional method to modern method and make market-oriented activities. Even though the impact of war damage has not been studied perfectly yet, the estimated report of BoARD showed that 70% of the bee colony population were lost due to genocidal war damage and previously introduced modern technology, small and large beekeeping cooperatives are severely damaged by the genocidal war in Tigray region. Likewise, individual beekeepers lost their bee colony, beekeeping equipment, materials and burned their apiary due to the war (WoARD, 2023). The beekeepers mentioned that the war was set in honey harvesting season and thus honey production was reduced as the entire honeybee colonies were not harvested in October 2019 and 2023.

The survey showed that an average of 4.3±4.53 honeybee colonies lost per household, about 70.86 kg of honey lost per household and 78293 ETB of total estimated birr lost from price of bee colony and honey due to war damage in the study area. The beekeepers replied that an average of 7.52±5.66, 2.77±2.05 and 2.48±3.14 honeybee colonies lost due to war in highland, midland and lowland areas at household level, respectively. Likewise, an average of 34.38, 90 and 88.2 kg of honey lost due to war per household in highland, midland and lowland areas, respectively. Similarly, an average of 57118, 90762 and 87000 ETB total estimated birr lost from price of bee colony and honey due to war damage in highland, midland and lowland areas, respectively (Table 33).

Table 33: Effect of Tigray war on beekeeping status of the study area (Mean±SD)

Effect of post war damage	Agro-ecology				
	Highland	Midland	Lowland	Overall	P-value
Colony lost due to war	7.52±5.655	2.77±2.053	2.48±3.143	4.3±4.533	0.00
Honey lost due to war in kg	34.38±120.87	90±93.5	88.2±116.54	70.86±113.32	0.009
Total estimated lost in ETB	57118±125393	90762±94644	87000±124827	78293±116184	0.222

As per the respondents, the genocidal war of Tigray severely damaged the beekeeping sector to decline in number of colonies, honey yield, swarming condition and economic lost in particular in the district area and generally in Tigray region. Accordingly, an average of 5.52 and 6.02 number of colonies owned by the respondents in 2019 and 2020, respectively in traditional hive before war, whereas an average of 3.24, 3.36 and 4.14 number of colonies owned by the respondent beekeepers in 2021, 2022, 2023, respectively in traditional hive after war (Figure 21).

Since the war was started at the honey harvesting season, most of the colonies were not harvested in Octobers 2021 and 2023. As a result, the harvested honey was declined due to the war. Accordingly, an average of 58.17 and 60.25 kg of honey were harvested from traditional hive in 2019 and 2020, respectively before war. While an average of 21.09, 23.21 and 13.38 kg of honey were harvested from traditional hive in 2021, 2022, 2023, respectively after war (Figure 21).

Consequently, the war affected the honeybee colony swarming condition and as a result an average of 2.01 and 2.59 number of bee colonies swarm in 2019 and 2020, respectively before war from traditional hive, whereas an average of 0.45, 1.02 and 1.54 bee colonies were swarmed in 2019, 2022, 2023, respectively after war from traditional hive (Figure 21).

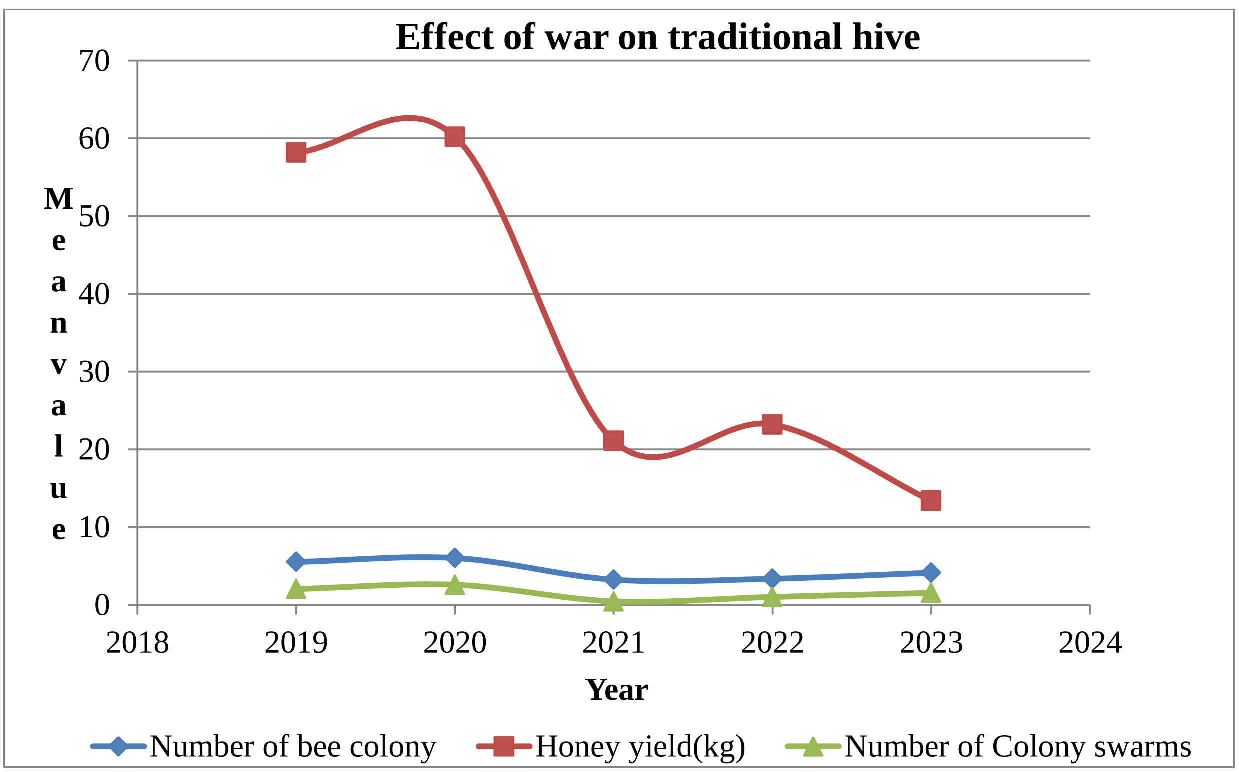

Figure 21: Trends of honeybee production before and after war in traditional hive

Similarly, in modern hives, an average of 1.19 and 1.17 number of colonies owned by the respondent beekeepers in 2019 and 2020, respectively before war, whereas an average of 0.44, 0.55 and 0.62 number of honey bee colonies owned in 2021, 2022, 2023, respectively after war (Figure 22). In addition, the harvested honey was declined due to the war in modern hives with an average of 25.6 and 25.97 kg of honey were harvested in 2019 and 2020, respectively before war. While an average of 5.87, 8.94 and 7.06 kg of honey were harvested in 2021, 2022, 2023, respectively after war (Figure 22). Similarly, the war affected the honeybee colony swarming condition and as a result in modern hive, an average of 0.1 and 0.09 number of colonies were swarmed in 2019 and 2020, respectively before war, whereas an average of 0.01, 0.03 and 0.06 number of colonies were swarmed in 2021, 2022, 2023, respectively after war from modern hive (Figure 22).

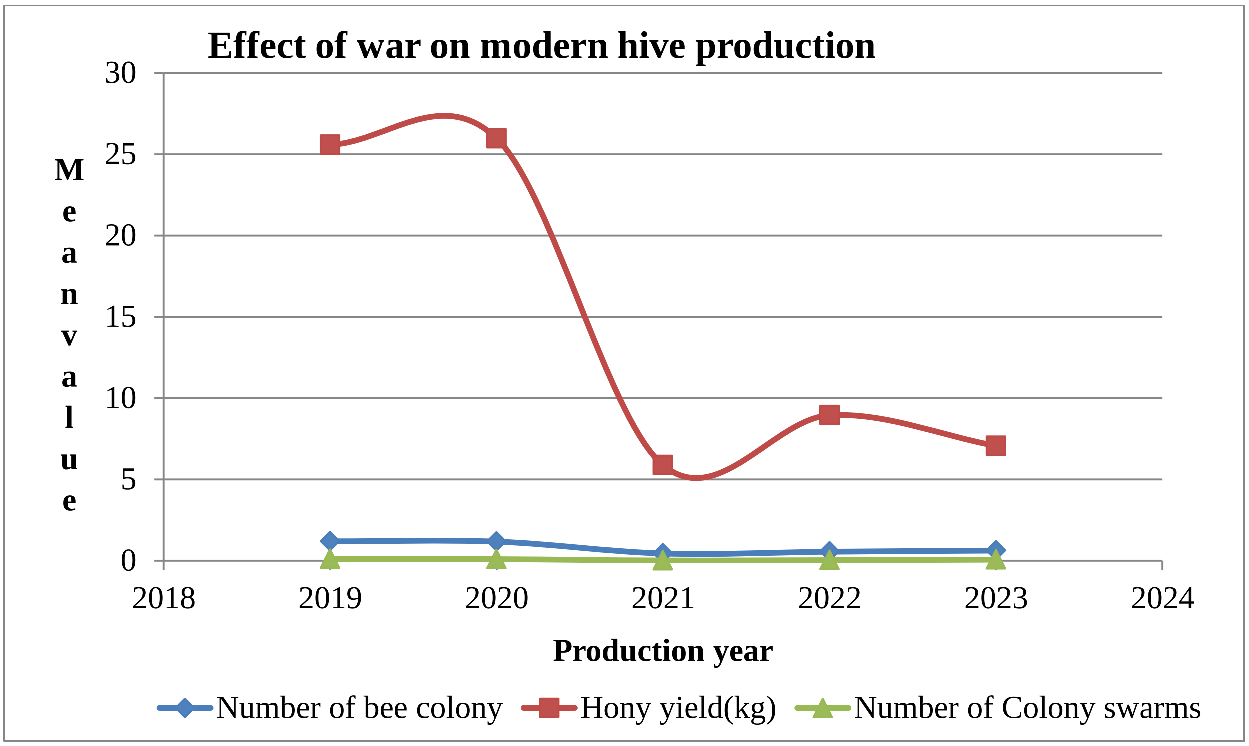

Figure 22: Trends of honeybee production before and after war in modern hive

Generally, this result indicates that about 38% and 70% of colony population in traditional and modern hive, respectively declined the colony ownership due to war damage in the district. Similarly, the result indicates that about 68% and 72% of honey from traditional hive and modern hive, respectively were lost due to war effect. Similar finding was reported by the impact assessment of BoARD of Tigray region. The result indicates that about 56% and 65% number of honeybee colony swarms from traditional and modern hive, respectively were lost due to war effect in the study district. This implies that the beekeeping sector is highly damaged by the war and the result is similar with impact assessment report of BoARD (70%).

4.11. Beekeeping services by different stakeholders in the study area

Extension and training packages are crucial for the government sectors for improved technology interventions as well as policy and regulations disseminations. Beekeeping training develops the beekeepers' self confidence in using technology and increases the productivity of the beekeepers. From this study, it was found that two modes of training prevail in the existing beekeeping system of the district, which is informal and formal training in improved beekeeping practices. Beekeepers receive training in traditional beekeeping methods from an experienced family member or local beekeepers which can be considered as informal training.

Formal training in improved beekeeping is offered by WoARD at different levels, development agents and some NGO's and only one beekeeper got training regionally. About 23% of the respondent beekeepers have got training in beekeeping activities on improved beekeeping practices with a mean of 1.8 days, whereas 77% of them had no chance of getting training. Out of the trained and non-trained respondent beekeepers, 96% of them need training. This as it is, about 25% and 45% of the respondent beekeepers in the highland and midland areas have got training, whereas no training chance was prevailed in lowland areas (Table 34).

This failure to render training will make the adoption of improved beekeeping practice reduced. There is weak public and NGOs support in the lowland areas, despite of the fact that there are many landless youths who need technical and managerial support from the concerned bodies.
According to this study, majority of the respondent beekeepers (59%) received beekeeping extension service on improved beekeeping technologies from the district development agents, while the rest beekeepers (41%) did not get any beekeeping extension service (Table 34).

Table 34: Capacity building and extension packages on honeybee colony in each agro-ecology

Items	Agro-ecology							
	Highland		Midland		Lowland		Overall	
	N	%	N	%	N	%	N	%
Importance of beekeeping	60	100	60	100	60	100	180	100
Beekeeping extension package	31	51.7	40	66.7	35	58.3	106	58.9
Training participation	15	25	27	45.0	0	0	42	23.3
Training need	59	98	55	91.7	59	98.3	173	96.1
Availability of Beekeeping accessories	2	3.3	0	0	0	0	2	1.1

N = Number of observations

About 52%, 67% and 58% of the beekeepers received extension service in highland, midland and lowland areas, respectively. Lower beekeeping extension services influence the adoption of improved beekeeping technologies. This result is in line with the result of Kiros and Tsegay (2017) who reported that about 62% respondents trained in near the towns followed by in the farmer training centres (FTCs) in eastern Tigray, Ethiopia. However, very rare trainings (8.3%) were given in regional city (Mekelle). Similar finding was also reported by Belie (2009) in which the sampled beekeepers (62.5%) were trained, while 37.5 % were not trained Burie district of Amhara region, Ethiopia.

Majority of these beekeepers reported that they cannot transfer the colony from local to frame hives and even those who can transfer were unable to harvest the honey. This might hamper beekeeping technology adoption process. Among those who are members of the extension service, 53% are extension package participants. Among the interviewed beekeepers, 38% of them had access to field day on bee keeping.

The study also showed that almost all the beekeepers did not have beekeeping equipment and accessories in the district area. The extension services focus on provision of inputs like smokers, frame beehives, beeswax, honey extractor, casting mould, beekeepers' suit, starter colony, and access of credit along with training on basic seasonal bee management and honey harvesting. Besides, newly engaged farmers are encouraged to buy frame beehives after training. This result indicates that there is a need of intensive training and encouragement in beekeeping on movable frame hives to move them to improved beekeeping systems. Empowering beekeepers with knowledge and skills ensures availability of modern technologies and increasing the beekeepers access to credit facilities. Similar results were reported by Workneh (2007*)* who noted that education increases the access to information and thereby possible knowledge of beekeepers regarding improved box hive. It also increases the understanding of the technology and practice of facilitates. However, an individual's level of formal education does not matter for successful beekeeping as most of the beekeepers in this study area are junior and illiterate.

Therefore, to facilitate and enhance the adoption of improved beekeeping practices, training on improved beekeeping practices should be given to selected beekeepers accompanied with provision of full productivity enhancing technology packages. The training can solve technical gaps and equip the beekeepers with basic knowledge on how to operate improved hives and bee equipment, basic bee biology, seasonal management and manipulate honeybee colonies, honey harvesting, transferring colony from traditional to frame hive, record keeping, grow appropriate bee forage plants, new processing techniques for production of higher quality products and its marketing. This result is in line with the result of (Addisu and Desalegn, 2021) who found that only 17.8% of the beekeepers received beekeeping extension service on improved beekeeping technologies from the district development agents. However, the majority of the respondents (82.2%) did not get any beekeeping extension service.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Beekeeping is an old practice in Ahferom district, Tigray region, Ethiopia. It is an ancient farming activity which is practiced as a side line with other farm activities but as a main income source. There are two types of beekeeping systems, those are traditional and modern hive based on the types of beehives used. The number of traditional and improved frame beehives owned per household varied among different agro ecology and beekeepers. The overall mean number of colony holding was 4.12 and 0.64 colonies per household in traditional and modern beekeepers, respectively. Most of the beekeepers in highland areas use swarm catching to establish their foundation stock, whereas buying in midland and lowland.

Based on physical appearance of body colour, black, red and mixed coloured bee types exist in the study area. Likewise, the honeybee colony types are classified as aggressive, docile and very aggressive based on their behaviour. Colonies are also categorized as big, medium and small based body size. Honey yield varies with hive type and locations. Honey production is more in lowlands and midlands than highlands. An average honey yield of 15.47 and 21.46 kg/ hive/year is obtained from traditional and modern hives, respectively. Honey production showed decreasing trends in all locations in the last five years (2019 to 2023). This was attributed to reduced colony/hive number and productivity per hive following the war.

Reproductive swarming is a common phenomenon in honeybee colony in Ahferom district. The phenomena are more pronounced in highlands than lowlands. Producing and marketing honeybee colonies are a common practice in Ahferom district. This is more common practice in highlands and midlands than lowlands. The lowlanders buy colonies from the highlanders. A single colony is sold at an average price of 3162 ETB (2500-4600 ETB) during the study year (2023).

Colony absconding is a major problem in beekeeping system of the area causing big economic loss. The phenomena are largely observed in traditional hives than modern hives due to the fact that traditional hives are difficulty for internal inspection. Post war effect, shortage of bee forages, pesticides and herbicide application, pests and predators and drought are the major causes of colony absconding in order of their importance. Pests and predators include birds, ants, spiders, swaps, small beetles, lizards, wax moths, honey badgers, toads, snakes and bee lice.

The beekeepers make both external and internal inspection of colony and apiary sites frequently. They provide supplementary feeds like sugar, *Besso* and *Shiro* to the colony during the dearth period (February to May). The beekeepers identified about 30 bee forage types in the areas with different habits (herbs, bushes and trees) and flowering calendar. From their long-time experience, the beekeepers identified also six poisonous bee flora.

The beekeepers have rich indigenous knowledge in hive management and utilization. These include reproductive swarming, bee sting prevention, bee sting pain minimization, bee colony strengthen, bee products as local medicine, disease investigation, disease control, honey harvesting season, smoking material, controlling reproductive swarming, biological control of honeybee enemies, swarm catching, identification of adulterated honey and increasing shelf life of honey.

The beekeepers have good experiences and indigenous knowledge in colony selection. The population of worker bees in the colony, colour of bees, direction of comb building, aggressiveness behaviour, and honey production potential, age of colony, pest and predator resistance, docile behavior, adaptability to the area and drought resistance are identified as the most important honeybee colony selection parameters.

About 38% and 70% of colony population in traditional and modern hive, respectively declined the colony ownership due to war damage in the district. Similarly, the result indicates that about 68% and 72% of honey from traditional hive and modern hive respectively were lost due to war effect. About 56% and 65% number of honeybee colony swarms from traditional and modern hive, respectively were lost due to war effect in the study district. An average of 4.26±4.53 honeybee colonies lost, and an average of 1212.69 ETB incomes lost from honey and a total estimated birr lost from bee colony and honey with an average of 76904.44 ETB per household due to war damage.

Application of agro-chemicals is a problem that seriously affecting the honeybee colonies. The colonies can abscond, die or perform less due the chemicals. This causes economic loss in the business. It was estimated about 131 colonies with estimated price 475,089.84 birr and 8445 kg of honey with estimated price 7,917,050 birr loss due to chemical application in the last years.

The beekeepers identified 14 constraints in the beekeeping business. These are pesticides and herbicides application, pests and predators, beekeeping equipment/ materials, shortage of bee forage, drought, absconding, death of colony, high wind, honeybee colony, high rainfall, shortage of water, high temperature, lack of bee hive and diseases ranked in order of importance. Despite all the constraints and challenges, there are still enormous opportunities and potentials to boost honey production of the area. The opportunities include availability of huge number of bee colonies, availability of honeybee floral resources, increasing hive products demand, employment opportunity, availability of micro finance institution and farmers willingness.

5.2. Recommendations

According to the results of this study, among the many issues that emerged, the suggested recommendations requiring consideration by development organizations for further intervention are highlighted below.

- Increasing the productivity and production performance of honeybee colony by improving the management of the traditional hives and introducing improved beehives, increasing the productiveness of bee colonies by improving bee forage and providing supplementary feed and introducing bee plants is very important.
- There is a need to provide adequate and practical training and strong extension services for both beekeepers and development agents. Therefore, establishing and supporting regular training programs to develop experienced and skilled experts, development agents and farmers in beekeeping management and marketing should be the major concern.
- Efforts should also be geared to alleviate the main constraints that hindered beekeeping production development in the district area. Therefore, there is a great need for attention in providing beekeeping equipment, awareness of farmers on minimizing of the effect of chemicals with involvement of regional government by developing strategies, and

planting multipurpose and drought resistant honey bee flora, conservation of existing vegetation, integrating beekeeping with agro-forestry and crop production is important.

- The effect of agrochemicals application on honeybees and means of minimization their effect should be addressed.
- Further studies shall be undertaken for confirming species diversity, structure and composition of honey bee flora and poisonous plant to bees.
- Further studies need to be carried out on the performance of honeybee colony types based on the effect of their morphometric characteristics and behavior in the district area.
- The natural reproductive colony swarming should be improved in to modern technology of honeybee colony multiplication methods.
- The honeybee colony selection criteria and indigenous knowledge of the beekeepers used should be scientifically approved or validated for further colony management practice.

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Appendix

Appendix I: Questionnaires used in the study

Mekelle University, College of Dry land Agriculture and Natural Resources, Department of Animal, Rangeland and Wildlife Science

Questionnaire for "Honeybee Production System, Colony selection criteria, and Performance in different agro-ecological zones of Ahferom district, Tigray, Northern Ethiopia"

Instruction
General
1.1 Name of interviewer:
1.2. Date of interview ____
1.3. Region _________________ 1.4. Zone
___________________1.5.Woreda___________________
1.6. PA/Tabia ________________ 1.7. Village (Got) _____________________
Part1. Household characteristics
1.1. Name of household head____
1.2. Sex of household: - 1.Male 2. Female
1.3. Age: - 1.18-30 2.31-45 3.46-65 4.66-75 5. Above 75
1.4. Marital status 1.Single 2.Married 3.Divorced 4.Widow 5. Widower
1.5 Educational level of household: - 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) ___________
1.6. Religion of the household 1= Orthodox 2= Muslim 3= other (specify)
1.7. Year of experience practiced in honeybee activities in the area __________.
1.8. Do you own livestock? 1= Yes 2= No
If yes, what type of livestock you have?

Livestock spp	Cattle	Sheep	Goat	Poultry	Donkey	Mule	Camel	
No								

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

If yes what is the size of land holding (Tsimad) ______

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

Crop type	Teff	Wheat	Barley	Maize	Sorghum	Pulses	Oil crops	Vegetable	Fruits
Tick									

Part2. Beekeeping Activities and Potentials

2.1. Honeybee ownership

2.1.1. Do you keep honeybees? 1. Yes 2. No

If yes, when did you start beekeeping? Traditional ________ modern hive ________year (s) ________

2.1.2. When did you start beekeeping? What is the source of your colony number used for the 1st time?

No	Source	Quantity	Traditional	Modern hive	Year of starting	Year of experience
1	Gift from parents					
2	Catching swarms					
3	Buying					
4	Trained					
5	Interest					
6	Inheritance					
7	Multiplication					
8	Others (specify)					

2.1.3. If your answer is multiplication, what methods you use? 1= Splitting 2=Overcrowding 3=others-

2.1.4. How do you use beekeeping? 1= Main income 2= Side line 3=Commercial

2.1.5. If your answer is main income, what is the rank of beekeeping in your livelihood? Put 1, 2 , 3 and 4.

1=Livestock______ 2=Crop____ 3=Beekeeping_____ 4=others (specify) _____________

2.1.6. If the answer for question 2.1.2 is buying, does the bee colony sale in your locality? 1. Yes 2. No

If yes, what is the price of one colony? 1. Strong___________ ETB 2.Weak __________ETB

2.1.8. How many honeybee colonies you owned?

	Years (EC)	Traditional hive			Modern hive		
		Colony	Total honey obtained(kg)	Honey yield kg/hive	No of movable frame with colony	Total honey obtained (kg)	Honey yield kg/hive
1	2015						
2	2014						
3	2013						
4	2012						
5	2011						

2.1.9. What is the trend of your bee colony number? 1= decrease 2=increase 3= no change 4. Unknown

2.1.10. What is the trend of your bee colony honey yield? 1= decrease 2= increase 3= no change 4. Unknown

2.1.11. 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	Causes	Rank	Season of occurrence	Control measures taken
1	Lack of bee forage			
2	Lack of water			
3	Drought (lack of rainfall)			
4	Migration			
5	Absconding			
6	Pests and predators			
7	Diseases			
8	Pesticides and herbicides application			
9	Death of colony			
10	Decrease in price of honey			
11	Increased cost of production			
12	Lack of credit			
13	Effect of war			
14	Others (specify)			

2.1.12. Where did you keep your bee colonies? 1=Backyard 2= Inside house 3=Closure areas 4= Hang on trees 5=others (specify)

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

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

2.1.14. Do you have empty beehives? 1. Yes 2. No

If yes, list the number of empty hives you have.

No	Types of hives	Number	Reasons (use causes of honeybee colonies absconding)
1	Traditional hive		
2	Movable-frame hive		

2.1.15. Does absconding occur in your colonies? 1. Yes 2. No

If yes, list the number of absconded hives you have

No	Types of hives	2015	2014	2013	2012	2011	Total number	Rank
1	Traditional hive							
2	Movable frame hive							
	Total							

2.1.16. In which hives your colonies do more likely abscond? 1. Traditional 2. Movable frame

2.1.17. What are the major causes for absconding? 1= Forage scarcity 2= pests &predators 3= disease & parasites 4=Weather 5. Chemicals 6.Others (specify)

2.1.18. What are the major pests and predators found in the area that threat your colonies? List in order of importance

No	Pests and predators	Rank	Season of occurrence	Effect*	Local control method
1	Ants				
2	Wax moth				
3	Bee lice				
4	Beetles				
5	Spiders				
6	Wasps				
7	*Prey mantis*				
8	Toads				
9	Lizard				
10	Snake				
11	Monkey				
12	Birds				
13	Hamagot/Shelemetmat/				
14	Others (specify)				

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

2.1.19. Do you observe any honeybee diseases in your apiary? 1. Yes 2.No

If yes, what are the diseases you observed?

No	Local name	Stage of bee affected		Symptoms	Incidence period	effect*	Local control measures
		adult	broad				

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

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

No	Types of hives	Answer(yes, no)	If yes put reason	Rank
1	Traditional			
2	Movable frames			

2.1.21. Which of your colonies were more likely to be infected by the above factor?

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

2.2. Honeybee colony behavioural characteristics and performance

2.2.1. What are the behavioural characteristic features of your honeybees?

Behaviour: 1. Docile______ 2.Aggressive _____ 3. Very aggressive _____

2.2.1.1 Which one is productive in terms of honey production and performance?

1=Docile 2= Medium 3=Aggressive

2.2.1.2. Which one is more defensive against any pests and diseases?

1=Docile 2=Medium 3= Aggressive

2.2.2. Colour: 1. Black 2.Red 3.Grey 4. Mixture

2.2.2.1. Which one is productive in terms of honey production and performance?

1. Black 2.Red 3.Grey 4.mixture

2.2.2.2. Which one is more defensive against any pests and diseases? 1. Black 2.Red 3.Grey 4.mixture
2.2.3. Size: 1. Big 2.Medium 3. Small
2.2.3.1. Which one is productive in terms of honey production and performance? 1. Big 2.Medium 3.small
2.2.3.2. Which one is more defensive against any pests and diseases? 1. Big 2.Medium 3.small
2.2.4. Which honeybee characteristic is more productive and good colony performance?
Behaviour: ____________________
Colour: ____________________
Size: ____________________

2.2.5. What are the colony performance evaluation factors?

Colony performance traits	Behaviour (aggressive, medium, docile)	Body colour (black, red, grey, mixed)	Body size (small, big, medium)	Production (high, middle, low)
Honey yield				
Brooding ability				
Colony strength				
Hygienic behaviour				
Foraging ability				
Pests and disease resistant				
Swarming tendency				
Absconding tendency				

Part3. Honeybee colony management

3.1. Do you visit and inspect your beehives and colonies? 1. Yes 2. No
If yes, which type of inspection you perform? 1. External hive inspection 1. Yes 2. No
2. Internal hive inspection 1. Yes 2. No
3.1.1. Frequency of inspection
3.1.1.1 External hive inspection: (circle one or more)
A. frequently B. sometimes C. rarely
3.1.1.2. Internal hive inspection: (circle one or more)
A. frequently B. sometimes C. rarely
3.1.1.3. If no inspection, what is the reason? ____________________
3.1.2. Do you clean your apiary? 1. Yes 2. No If no why? ____________________
3.1.3. When the following major activities occur in your locality? (tick)

No	Major activities	Seasons of occurrence			
		September to November	December to February	March to May	June to August
1	Brood rearing period				
2	Colony Swarming				
3	Colony Migration				
4	Colony Absconding				
5	Honey flow season				
6	Honey harvesting time				
7	Dearth period				

3.1.4. Did you feed your honeybee colonies? 1. Yes 2. No

If yes, when do you feed your honeybees? (Months): ____________________

3.1.4.1. What kind of feed you offer to your honeybees?

No	Types of feed	Amount of feed offered per season /colony	Months offering feed	Reason of feeding honeybee colony
1	Besso			
2	Shiro			
3	Sugar syrup			
4	Honey + Water			
5	Others (specify)			

Part4. Honeybee colony swarming activities

4.1. Does swarming occur in your colonies or locality? 1. Yes 2.No

If your response is yes, what is the frequency? (Circle)

1. Every season 2. Every year 3. Once in two years___ 4.Others, specify:____________

4.1.1. If your response is yes for question no 4.1 how many swarms per colony? ______________

4.2. How many of the swarmed colony is selected for the next generation? __________________

4.3. When does swarming occur more frequently? (Months) From__________________ to______

4.4. Is swarming advantageous to you? 1. Yes 2. No

If yes, describe the reason(s)(Circle one or more)

1. To increase my number of colony
2. To sale and get income
3. To replace non-productive bee colonies
4. Others specify: ____

If no, describe the reason____

4.5. Do you have swarms catching experience? 1. Yes 2. No

4.6. How many swarms do you catch in this production year? ______________________________

4.7. Based on the above swarming activities which hive is the best of you?

1. Traditional 2. Movable frame

4.8. What are the major limitations of your beehives?

4.8.1. Traditional hive

1.__________________________________ 2. ____________________________________

3. ____

4.8.2. Movable-frame hive

1.________________________________ 2._____________________________________

3. ____

4.9. What kind of beehive products you produce? List the amount of your beehive products and frequency of harvest per annum.

No	Products	Traditional		Movable frame		Honey Hunting	
		Kg/hive	Frequency	Kg/hive	Frequency	Kg/hive	Frequency
1	Honey						
2	Crude beeswax						
3	Propolis						

4.10. What types of honey you produced?

Honey type	1=Yes 2=No	Common (Rank)	Market place (Tick one or more)					Honey price ETB per kg at	
			Farm gate	Wereda market	3.outside wereda	Jeg house	No sale	Market place	Farm gate
White									
Yellow									
Red									
Sergen									
Others									

4.11. Do you collect crude beeswax 1. Yes 2. No

4.11.1. Why you are collecting crude beeswax? (Circle one or more)

1. For income generation
2. Candle making
3. Foundation sheet making
4. Religious and cultural use
5. Others, specify:____

4.11.2. If you don't collect/produce beeswax what is (are) the reason (s)? (Circle one or more)

1. Lack of market
2. Lack of knowledge
3. Lack of processing skills
4. Lack of processing materials 5. Others specify:

____

4.12. Do you collect propolis? 1. Yes 2. No

If yes, for what purpose you are using the propolis? (Circle one or more)

1. For sale (marketing)
2. as a medicine to treat diseases
3. Others specify: ____

If your response is no, what is (are) the reason (s)? (Circle one or more)

1. Lack of market 2. Lack of knowledge 3. Others specify ______________________________

Part5. Honeybee flora and their flowering season

5.1. Is there availability of bee forage in your locality? 1. Yes 2. No

5.1. 1. If yes, what are the major honeybee floras in your area? List in terms of priority?

No	Major bee flora	Local name	Plant Habit	Flowering season
1				
2				
3				
4				

5.2. Is there any poisonous plant to bees in your area? 1. Yes 2. No

If yes, mention those poisonous plants and their flowering time.

No	poisonous plants	Local name	Plant Habit	Flowering season
1				
2				
3				
4				
5				
6				

Part 6. What is the indigenous Knowledge of Beekeeping in your localities?

No	Descriptions	Indigenous knowledge
1	Reproductive swarming	
2	Bee sting prevention	
3	Bee sting pain minimization	
4	Bee colony strengthen	
5	Bee product as local medicine	
6	Disease investigation	
7	Disease control	
8	Adulterated honey	
9	Honey harvesting season	
10	Increase shelf life of honey	
11	smoking materials	

Part7. Opportunities and Constraints of beekeeping production system

7.1. What are the major constraints of beekeeping production system in the area? (Rank them)

No	Constraints	Rank	What local measures will be taken?
1	Bee hives		
2	Beekeeping equipment / materials		
3	Honeybee colony		
4	Shortage of bee forage		
5	Shortage of water		
6	Drought (lack of rainfall)		
7	Absconding		
8	Pests and predators		
9	Diseases		
10	High temperature		
11	High wind		
12	High rainfall		
13	Pesticides and herbicides application		
14	Death of colony		
15	Migration		
16	Swarming		
17	Storage facilities		
18	Marketing		
19	Others (specify)		

7.2. From your point of view what are the opportunities for beekeeping in your area?

No	Opportunities	Rank	What measures will be taken?
1	Presence of bee forage resources		
2	Have cheap human resources		
3	Access of beekeeping technology Packages		
4	Good market demand for honey		
5	High market demand bee colony/queen		
6	Available governmental and non-governmental technical support		
7	Presence of microfinance institutions at grass root level		

7.3. Does beekeeping profitable to the area? 1. Yes 2. No

7.4. Do you participate in beekeeping extension packages? 1. Yes 2. No

7.5. Do you get beekeeping training? 1. Yes 2. No

If your response is yes:

No	Places of training	Duration	Organized by
1			
2			
3			

7.5.1. If your response for question 8.5 is no, do you need beekeeping training? 1. Yes 2. No

7.6. Do you have any beekeeping accessories? 1. Yes 2. No

7.7. If yes, which accessories did you have and use in the last three year?

1		3	
2		4	

Part8. Agrochemicals

8.1. Do you use agrochemicals/chemicals in your locality? 1. Yes 2. No

If yes, why do you apply agrochemicals/chemicals?

1. Crop pests control
2. Weeds control
3. Malaria control
4. Livestock acaricid control
5. Others (specify): ____

8.1.1. When do you use agrochemicals/chemicals (months)? ______________________

8.1.2. What type of agrochemicals/chemicals are farmers using? ____________________

8.1.3. Do agrochemicals/chemicals affect your honeybees? 1. Yes 2. No

If yes, how many colonies did you lost due to chemicals? When? (Year and months)

Years (Ec)	Abscond	Dwindled	Died	Migrate	
2015					
2014					
2013					
2012					
2011					

8.2. What is the estimated honey you lose? _____ kilogram, What will be the estimated price? ______ETB

8.3. What measures do you take to protect your bee colonies from Agrochemicals/chemicals? __

Part 9: Marketing Condition

9.1. Honeybee products marketing

9.1.1. Do you sale your honey? 1. Yes 2. No

9.1.2. What are the factors that govern the price of the honey in your locality? (Circle one or more)

1. Seasons of the year 2. Colours and taste of the honey 3. Distance from market
4. Traditional ceremonies 5. Quality/purity of honey 6. Others (specify): ______

9.1.3. During this harvesting season what is the price of 1 kg of honey?

No	Colour of honey	Price of honey (Birr/kg) produced from	
		Traditional hive	Movable frame hive
1	White		
2	Red		
3	Brown		
4	Mixed		

9.2. **Honeybee colony marketing**

9.2.1. Do you practice colony multiplication and sale honeybee colony in your locality/Woreda?

1. Yes 2. No

If yes, what type of honeybee multiplication do you practice in the area? 1. Swarming 2. Colony splitting

If yes, how many honeybee colonies do you sale annually? ___________________ Colonies

9.2.2. Do you buy honeybee colony in your locality/Woreda? 1. Yes 2. No

9.2.3. What type of honeybee colony selection criteria do you use locally during production, multiplication and marketing? List and rank them in order of importance.

No	Types of selection criteria	Rank	Description of beekeepers on honeybee colony selection criteria
1	Honey production		
2	Aggressiveness		
3	Body colour and size		
4	Drought resistance		
5	Adaptability to the area		
6	Based on colony age		
7	Bee population		
8	wax production		
9	Absconding		
10	Swarming		
11	Behavior(docile)		
12	Disease and pest resistance		
13	Ability to forage from long distance		
14	Comb building direction		
15	Others specify them		

Part10. Beekeeping condition trends before and post war

10.1. Do affect war on beekeeping production system in your locality? 1. Yes 2. No

If yes, what are the impact of war on beekeeping condition and trends in your locality and your bee colony before and after war? List them.

Types of bee hive	Before war/pre-war						After war/post war								
	2011			2012			2013			2014			2015		
	Colony	Honey	Swarms	Colony	Honey	Swarms	Colony	honey	Swarms	colony	honey	Swarms	Colony	honey	Swarms
Traditional															
Modern															
Total															

Compiler: Name Tuemay Wendim Mesfin

Signature _____________________

Date - 30/1/2024

Duration: Starting time- February Ending time – April

Appendix II: different photos in the study areas

Figure 23: Honeybee colony placement in the district area

Figure 24: Honeybee colony providing water at drought season

Figure 25: Poisonous plant (Brbra) to honeybee colony

Figure 26: Honeybee bee flora at lowland area

Appendix III: different tables

Table 35: Colony absconding in traditional and modern hive in each agro-ecology

Absconding trends		Agro-ecologies												
		Highland			Midland			Lowland			District			P-value
		F	%	Colony	F	%	Colony	F	%	colony	F	%	colony	
Occurrence of colony absconding (Empty)	Yes	59	98	579	52	86.7	215	54	90	193	165	91.7	987	0.03
	No	1	2		9	13.3		6	10		16	8.9		
	Total	60	100		60	100		60	100	193	180	100	987	
Number of Absconded colony in traditional hive	2023	23	38	45	6	10	8	3	5	23	32	17.8	76	0.11
	2022	18	30	41	12	20	17	2	3.3	2	32	17.8	60	0.00
	2021	57	95	391	42	70	88	51	85	95	150	83.3	574	0.00
	2020	21	35	36	6	10	10	13	21.7	14	40	22.2	60	0.00
	2019	24	40	42	10	16.7	18	9	15	12	43	23.9	72	0.00
Total absconded colony from traditional		57	95	555	45	75	141	53	88.3	146	155	86.1	842	0.00
Number of absconded colony in modern hive	2023	0	0	0	3	5	3	4	6.7	9	7	3.9	12	0.12
	2022	1	1.7	2	3	5	5	1	1.7	1	5	2.8	8	0.44
	2021	18	30	33	26	43.3	69	20	33.3	35	64	35.6	137	0.02
	2020	2	3.3	2	0	0	0	3	5	4	5	2.8	6	0.31
	2019	2	3	10	1	1.7	1	0	0	0	3	1.7	11	0.17
Total absconded colony from modern hive		17	28	39	29	48.3	79	22	36.7	49	68	37.8	167	0.06

F= Frequency N= Number of observations (N = 180)