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Assessment of Honey Production System, Bee Forage Diversity and Honey Quality of Gemechis Forest, West Hararghe Zone, Oromia Region, Ethiopia

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Abstract

The study was conducted in Gemachis forest from October 2019 to November 2020, which is an important area of biodiversity conservation, tourism and carbon sequestration for modulating climate change. The forest is also very important for honey production and other non-timber forest products. The study was designed with the objective of assessing honey production system, honey bee flora diversity and assessing of honey quality of forest. From study district, two rural kebeles surrounding the Gemachis forest, 29 beekeepers were selected using purposive sampling techniques. For the inventory of bee forages a transect line were made in three selected altitudinal strata. Honey samples, were obtained from the three agro ecologies of the forest: Arer, Chafe kebene and Sororo. The pollen spectrum of the honey was analyzed to determine the botanical and geographical origin of the honey. The quality parameters considered were, Moisture content, ASH, HMF, Free Acidity, and PH. According to inventory of the honeybee flora forty-eight (48) bee plant species were identified; belonging to 33 families of which Fabaceae, Roseaceae and Verbenaceae were the most frequent families in the study area. Among these bee forages 54.1% were shrub 16.6% were trees and 29.1% were herbs. From identified bee forages, Solanium spp, Andropogon abyssinica, Guizotia spp and Hypoestes forskaolii were the most abundant bee flora species in the study area. The pollen analysis of honey revealed that, two types of monofloral honey types were identified in the area which includes Guizotia spp and Eucalyptus globulus accounting for 74.9% and 54.9% pollen frequency respectively. The analysis of honey quality indicated that moisture content was higher in honeys from chafe kebena than honeys from the other two sites with a mean value of 22.3%. The hydroxymethylfurfural (HMF) content was very low and ranged between 0.7 and 11.00 mg kg-1. Except for the moisture content, results produced in Gemachis forest present excellent quality parameters according to international standards. Majority (82.8%) of the beekeepers owned the traditional hives and only 3.4% of the beekeepers owned moveable frame hives. The average beekeeping experience of the beekeepers was 11.24 years with the range varying from 1 to 30 years. Pesticides, honey bee enemies, disease and drought were the major constraints of beekeeping in the area. Thus, beekeepers should adopt modern beekeeping technology and conserve the forest for sustainable honey production since the forest is endowed with good bee plant diversity.

Keywords: Botanical origin; honeybee flora; Gemachis forest; physicochemical parameter.

Introduction

Background and Justification

Apiculture is an ancient agricultural practice in Ethiopian farming communities and it has been exercised as a sideline activity. It seems as old as the history of the country and it is deep-rooted within life style of many of the rural farming that contributes to income generation and household food security. It is a major integral component of Agricultural economy of the country through collection and marketing of bee products such as honey and beeswax and other hive products (royal jelly, propolis, bee venom) providing nutritional requirements, ecological conservation and income to the community. Apart from this it provides employment opportunities and it helps in financial security as whole.

In Ethiopia incredible variation of agro-climatic conditions and topographical variation favored the existence of diversified honeybee flora and huge number of honeybee colonies. On top of this diversified agro- climatic conditions of the country created suitable environmental conditions for the growth of 6000 to 7000 species of flowering plants of which most of them are bee plants. From these bee plants over 800 bee plants are identified and documented.

The country has the highest honeybee population in Africa which is estimated about 10 million bee colonies, out of which about 5 to 7.5 million are estimated to be hived while the remaining exists in the wild . More over about 4,601,806 hives exist in Ethiopia out of which about 95.5% are traditional, 4.3% transitional and 0.20% frame hives [1]. Currently, the honey production potential of the country is 500,000 metric tons per annum. However, the recent the annual honey production of Ethiopia only 54,000 metric tons of honey and 5,000 tons of beeswax making one of the 10 top honey producing country in the world and first in Africa and ninth in the world.

Beekeeping plays an important role in conserving the natural resources and contributes to the globe through environmental protection. Several studies have shown that forest management and beekeeping have had a long history of interdependence in the world because beekeeping dovetails naturally with agro-forestry for the functioning of the ecosystem, biodiversity conservation, honey production and crop pollination. For instance, in Kenya, charcoal burning was successfully reduced by introducing beekeeping as an

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alternative economic activity. On top of this the contribution of honeybee pollination to crop production and quality has been estimated to be more than the value of honey and wax production.

The availability of pollen and nectar yield plants in the different habitats including both in agricultural landscapes and natural forest are the most limiting factors for honey production as well as for the growth and reproduction of honeybee colonies (*Apis mellifera L*). Nectar and pollen provide the nutritional requirements of the honeybee colonies. Nectar is a product of photosynthesis derived from the phloem tissue and is available as floral reward for different pollinators including honeybees.

The availability of floral resources to honeybees varies according to several factors such as distance from colonies, species-specific flowering phonology, tree size, and spatial distribution of honeybee plants, which in turn determine the carrying capacity of the area. The carrying capacity of the beekeeping is the number bee colonies it can support which depend on, abundance, flowering calendar of bee plants. Flowering calendar of bee plant is an important tool that informs the availability of certain bee forage for particular area, to predict time of honey flow period and their values to bees.

Gemechis mountain forest is one of the remaining patches of forests in West Hararghe zone. According to Gemachis forest is composed of fifty-one (51) woody species belonging to 50 genera and 34 families. This is composed of 64.7% of the tree, 31.3% shrubs and 3.9% of lianas. The forest has strong ecological and economical importance for the surrounding community as source of water, fuel wood and habitat for different wild animals [2]. The forest has a great potential for beekeeping development due to presence of diversity of bee forage and beekeeping practice that may contribute to improving the livelihood of the surrounding communities. However, the forest is under continuous threat by expansion of human population pressure from all sides. Owing to such a human pressure, trees and under-story plants used for honey production are under threat resulting in loss of biodiversity and affecting traditional apiculture.

Statement of the Problem

Honeybee health depends on forage availability amongst other things with great quantity and quality of the forage, if forage is not available or accessible, to honeybees the desired bee products from beekeeping would cease to exist, taking away all the derived benefits from beekeeping. Thus, identification and documentation of bee forages for beekeeping production are important factor for the survival of honeybees and for production of bee products for income generation and conservation of the forest without affecting the forest in the area.

The smallholder beekeepers surrounding the forest in the district are producing honey for the purpose of income generation and it is main source of income for the family. The farmers produce honey using traditional methods and selling their honey to the local market but beekeepers lack sufficient information about the honey quality. As the result the product quality has always been low leading to high domestic utilization, and low export earnings.

According to the definition of the other international honey standards, honey shall not have added any food ingredient than honey to it nor shall any particular constituent be removed from it. Honey is subjected to adulterations with inexpensive sweeteners such as corn syrups (CS), high fructose corn syrups (HFCS), invert syrups (IS) or high fructose insulin syrups (HFIS). The adulteration of honey with invert sugar or syrup may not readily be detected by direct sugar analysis because its constituents are the major natural components of honey and the adulterated product would also have similar physical properties to natural honey. Therefore, the quality standard of honey in the study areas needs to be verified against national and international standards. Due to these it is important to explore about the major honeybee flora and to determine honey quality produced by surrounding farmers in the study area [3].

Objectives of the Study

General Objective: The main objective of the study was to assess honey production system, honeybee flora diversity and honey quality in Gemchis forest.

Specific Objectives: To study the bee forage abundance and diversity of Gemachis forest

To assess botanical origin of honey

To determine physiochemical properties of honey of Gemachis forest

To assess honey production system in the study area

Literature Review

Beekeeping Practices in Ethiopia

In Ethiopia three systems of beekeeping are said to exist, namely honey hunting, forest beekeeping and backyard beekeeping.

Honey Hunting: - is a system looking for honey without taking care of the bee colonies. Honey hunters search for honey in caves, crevices of stones, hallow trunks of wood, etc. Using fire flame, water and other materials to displaces the colony. Honey hunting is common in this part of the country because of the existence of high population of wild bee colonies which make honey in hollow trees and caves. This practice still exists in some areas of the country particularly in Bench-Majii zone and practiced by Mezhenger tribe, in south west Ethiopia.

Forest Beekeeping: - This is hanging of hives on tree branches for harvesting honey during the honey flow period without taking care of the bees; this is not also widely practiced except that hives are hung on trees to catch swarms and taken home when occupied by bees. The traditional forest beekeeping is practiced in south and southwest areas of Ethiopia where there is high vegetation cover and high honeybee colonies. In this case the beekeepers hang several traditional hives on trees in the dense forest mostly, far away from their settlement areas.

Backyard Beekeeping: These systems of beekeeping in which the beekeepers take care of their bees providing with shelter, water, and feed and protect them from bee enemies. In this system, bees are managed in hives both indoor or outdoor apiaries and several million bees' colonies are managed with the same traditional beekeeping methods in almost all parts of the country.

This system of beekeeping is mainly practiced in the central, eastern and northern parts of the country where there is relatively low forest coverage.

Advantages of Beekeeping

Beekeeping has the potential to help many people to increase their incomes and their crop yields. As very little space is needed, beekeeping is ideal for people who have no land and little space and little money. They have chance for many landless peasants and small holders to improve their livelihoods. They go on to say any source of food or income that does not need land is potentially important.

Beekeeping is such an undertaking because beehives occupy minimal space and can be placed on west land. Beekeeping does not compete with other types of agriculture for resources, but produces food from natural resources that are not otherwise exploited [4]. It improves the ecology and it helps in plant reproduction through pollination services of honeybees. Bees do not over-graze as other animals do.

Beekeeping has many attractions for rural farmers. It is cheap, and it does not involve mass feeding of bees, because honeybees can provide their own food all year round, and there is no over wintering bee management. Bees do not require daily attention and beekeeping does not take up valuable land or time, which would have been spent on other farming activities. Males and females of all age groups can practice it and it helps to create self-reliance. It does not depend on importation of foreign equipment or inputs. Individuals and private organizations such as churches, women's groups, youth associations and cooperative societies can initiate it with only limited funds.

Ethiopia is blessed with plenty of water resources and wide range of honeybee floras, which make productive ground for the development of beekeeping. Honey hunting and beekeeping have been practiced in the country for the production of honey and beeswax. In areas where wild colonies of bees living in hollow trees and caves are found, honey hunting is still a common practice in Ethiopia. Presently, in the country Traditional, Transitional and Modern beekeeping methods are exercised.

Traditional System of Beekeeping: Traditional beekeeping is the oldest and the richest practice in Ethiopia which has been carried out by the people for thousands of years. Several million bee colonies are managed with the same old traditional methods in almost all parts of the country.

Traditional beekeeping is of two types: forest beekeeping and backyard beekeeping. In some places, especially in the western and southern parts of the country, forest beekeeping by hanging a number of traditional hives on trees is widely practiced. In other most parts of the country backyard beekeeping with relatively better management are common.

Traditional beekeeping is mostly practiced with different types of traditional hives. The most universal type of traditional hives, known to have been in use is simple cylindrical type. Beekeeping started with traditional or fixed comb hives, so called because the combs are attached to the top and sides of the hive itself and the beekeeper cannot easily remove and replace them. In its primitive form, only one end of the hive could be open, but in more advanced forms each end of the cylinder will be fitted with a removable closure. The types of hives and the way of keeping bees vary from area to area. Based on locally available materials used for construction of hives, environmental conditions and positions used to keep bees, the following variants of basic design are found throughout the country: hollowed logs, bark hive, bamboo or reed grass hive, mud (clay) hive, animal dung (mixed with ash) hive, woven straw hive, gourd hive, earthen pot hive and so on.

The beekeepers that are experienced and skill fully in using these hives could do many operations with less facility. Stated that under Ethiopian farmers' management condition, the average amount of crude honey produced from traditional hive is estimated to be 5 kg / hive / year. On the other hand, based on the survey conducted in West Showa Zone, the amount of honey harvested, from a traditional hive on average was reported to be 6.1 kg/hive/year.

Traditional husbandry is practiced with many millions of fixed comb hives particularly in the remote areas of the country. For the period until modern frame-hives are introduced, these fixed comb hives can yield the modest amount of honey, and also about 8-10% of its weight is beeswax [5]. This harvest is achieved with minimal cost and labor, and it is valuable to people living a marginal existence.

Transitional System of Beekeeping: This type of beekeeping is intermediating between traditional and modern beekeeping methods. It is one of the improved methods of beekeeping practices. The types of hives are Kenya top Bar Hive (KTBH) and Tanzania Top Bar Hive (TTBH). The hives can be constructed from timber, mud or locally available materials. Each hive carries 27-30 top bars on which honeybees attach their combs. The top bars have 3.2cm and 48.3cm width and length, respectively.

Technical and economic reasons, most African countries are not yet in the position to use movable- frame hives, and for them top- bar hive represents a satisfactory compromise. 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.

Modern System of Beekeeping: Modern beekeeping methods intend to gain the maximum honey, season after season, without harming bees. Modern movable- frame hive consists of precisely made rectangular box hives (hive bodies) superimposed one above the other in a tier. The number of boxes is varied seasonally according to the population size of bees. Practical movable- frame hive was invented in 1851 by Lorenzo Lorraine Langstroth in U.S.A. Later on different countries developed their own movable frame hives (for instance Zander, Dadant) and Langstroth was the prototype of movable frame hives used today. In many countries Langstroth hive boxes have proved to be convenient for handling and management.

In Ethiopia, about 5 types of movable frame hives were introduced since 1970 the most commonly used ones are: Zander and Langstroth style hives. Based on the national estimate, the average yield of pure honey from frames hive is 15-20 kg/year, and the amount of beeswax produced is 1-2% of the honey yield. However, in potential areas, up to 50-60 kg harvest has been reported. Movable frame hives allow colony management and use of a higher level of technology, with larger colonies, and can give higher yield and quality honey but are likely require high investment cost and trained man power.

Potential Bee Forage in Ethiopia

Beekeeping is one of the most important farming activities in Ethiopia. According to the previous study of Ethiopia has longer tradition on beekeeping than any country in the world. "Since the 4th century during the time of king Ezana, Christianity with strong emphasis on nomadic culture had a greater contribution for intensive growth of apiculture; because of the need for wax and honey needed for religious ceremonies and for making traditional beverages". Hence, beekeeping practice has been estimated that started five thousand years ago in the northern regions [6].

Ethiopia has a great potential in beekeeping because of diversified agro climatic conditions of country has endowed with 7,000 plant species which support foraging bees and many other insects . Therefore, due to this availability of diversified bee flora and other environmental factors, Ethiopia has the highest bee density and is the largest honey producer in Africa and 10th in the world. Hence, in Ethiopia beekeeping is one of the oldest agricultural practices having passed from generation

to generation without modification up to present time. It is only about 3 decades since improved beekeeping has been started in Ethiopia by introducing movable frame hives (Ayalew, 2004); this improvement makes beekeeping one of the good and best agricultural businesses and one of the income streams for rural peoples.

However, the yield and price of honey depend on the potentiality of the local area for beekeeping and hive management. According the most important honey and beeswax producing regions in Ethiopia are Oromia which accounts 51% of honeybee colonies and 38% of the honey production, followed by Amhara which accounts for about 21% of the colonies and 26% of the honey production. The Southern Nations, Nationalities Peoples Regional State, on the other hand, accounts for about 18% of the bee colonies and 18% of the honey production. While Tigray and Benshangul-Gumuz accounts for 5% and 4% of the total bee colonies, and 8% and 7% of the total honey production, respectively.

The diversified flowering plants in Ethiopia and their blooming season greatly vary from place to place; this enables the country to sustain a large number of honeybee colonies [7]. About 500 honeybee flora species were identified by the previous study with their importance for honeybees (as source of pollen and/or nectar). For example, species such as: *Eucalyptus camaldulensis, Optica cylinderica, Euphorbia candelabrum* and *Olea europeae* are some of the major bee tree species as source of both pollen and nectar to honeybees. In addition to *Leucas abyssinica, Becium grandiflorum, Carissa edulis, Leucaena leucocephala* etc. are good source of pollen and nectar. While *Zea mays* and *Ocimium basilicum* are some of the honeybee flora plants which are sources of only pollen and nectar, respectively. As honeybee plants can be categorized as major and minor source of bee forage.

Major bee plants: Major bee plants are plants that frequently visited by honeybees for nectar and pollen throughout their flowering period. E.g. *Bidens spp*, (meskel flower), *Trifolium spp*. (Clover), *Eucalyptus spp*. *Acacia* spp. and *Vernonia spp*.

Minor bee plants: Are those plants that are visited less often by bees or only when flowers of major bee plants are not in flower. E.g. *Echinopes spp* (Koshoshila), *Solanum spp* (Imboay), *Dovyalis abyssinica* (koshim) and *Sida spp* (chiferge).

Bee Forage and its Role for Honeybees

According to plants are the food sources to honeybees. However, not all plants are important for honeybee and those plants that supply both nectar and pollen abundantly when in bloom and these are often called honeybee plants; honeybee plants are best suited for honey production as well as colony maintenance, in those honeybees obtain protein from pollen source plants and carbohydrate from nectar source plants.

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. Based on study conducted by honeybees often forage on leguminous plant species, whether trees or ground covers such as clovers (*Trifolium spp*). Honeybees also collect large quantities of pollen from *Zea mays*. Pollen plants are important in beekeeping, especially at the time of colony build-up [8]. Generally, assessing the potential bee flora and their importance as a major or minor for honeybee plant is very important in seasonal colony management. According to a study conducted in Zaria northern Nigeria, about 57.1% of the bee visited plants are perennials while 42.9% are annuals. Noted that many plants produce pollen for the bees, it is usually nectar producing species that are the most interesting for beekeepers except few plants; and the most reliable nectar producers are: Gallberry, Citrus, Tupelo saw palmetto, Melaleuca, Brazilian pepper and Palm (cabbage).

Revealed that in planning a bee pasture is important to choose a collection of plants that will produce continuous succession of bloom throughout the season. One way is to improve bee nutrition (ultimately, increasing their populations) by planting or encouraging more-or-less permanent bee pasture near the crop of interest, such as trees, bushes and woody perennials.

Floral calendar of honeybee plants

The floral calendar for beekeeping is a time-table that indicates to the beekeeper; the approximate date and duration of the blossoming periods of the important honey and pollen plants. When we see the flowering time of single species, it begins from the full opening of the first few buds till the start of fruit formation end of flowering.

The distribution and type of honeybee plants as well as their flowering duration varies from one place to another place due to variation in topography, climate, and farming practices. Hence, every region has its own honey flow and floral dearth periods of short or long duration and this knowledge on bee flora helps in the effective management of bee colony during such periods [9].

For instance in Ethiopia honey flow period is after the heavy rain in July through September known as "Kremt" and most of the Ethiopian highlands are colored with golden-yellow because of abundance of the flower of Bidens species, indigenous oil crops like *Guizotica abyssinica* (Noug), *Helianthus annus* (sunflower), *Brassica carinata*, (rape seed) and *Trifloum spp* with red violent colors . In Bure District also the potential bee floras are studied with their flowering calendar and the flowering time of *Biden spp, Clematis hirusta, Pisum sativa, Zea mays* was found to be flower from September to October, and that of *Carissa edulis* and *Eucalptus spp* was from March to May whereas for *Croton macrostchyus* it was from May to June. From the analysis of the flowering periods of the bee plants through field interviews, it was possible to identify honey flow seasons, in Rift valley regions of East Shewa zone and it was found to be occurring from September to October as well as from April to June.

Generally, the flowering calendars can make easier to plan various beekeeping management operations such as the sitting of hives near to particular crops and deciding the best time for honey harvest and/ or colony swarming. Hence adequate knowledge about bee flora including the floral calendar is the prerequisite to initiate beekeeping.

Seasonal Colony Strength in Relation to Forage Availability

The colony strength as well as honeybee products mostly depend on the availability and type of bee flora next to level of colony management practice. The bees foraging at least 1.5 km from their colonies, and the proportion of foragers flying to one field declined, approximately linearly, with radial distance. Hence, apiary site should be near by the good bee forage plants in order to obtain good honeybee products and colony strength.

Also illustrated those in order to survive prosper and be productive; honeybee colonies must have a supply of both nectar and pollen in adequate quantities. Consequently, the performance of the colony, either weak or strong as well as honey flow period of the colony directly depends on the existing availability of bee flora in each season.

Previous study in Ibadan (south west of Nigeria) by , found out that; the main nectar flow is from July to February, with a peak in January

when the largest forest trees are in flower, as a result, at this time there is enough nectar flow and the colony is strong with surplus honey to harvest. Other studies by at Kabre, Dolakha district also indicated that the peak periods of honeybee foraging activity and abundant bee floral plants were recorded during mid-February and May (spring season); whereas from mid-November to February (winter season) is dearth period and the colony strength can be weak with little or no honey production in addition to the colony may abscond. Therefore, honeybees can live only if they have forgeable plants.

Explained that the best harvesting period should be before the start of the dearth period when few plants are flowering [10]. This is the time when feeding of bees is advised to prevent absconding, and to ensure the colony remains strong enough for the forthcoming season.

Honey

Honey is a natural sweet substance produced by honeybees from the nectar of blossoms, from secretion of living parts of plants. Honeybees collect this material, transform and combine it with specific substances of their own, store and leave in the honeycomb to ripen and mature. Freshly extracted honey is a viscous liquid, has a greater density (1.5 g/cm3) than water (1 g/cm3 at 4 °C), having a strong hygroscopic character. The color, aroma and consistency of honey all depend upon which flowers the bees have been visited. The various chemical components of honey include: carbohydrates that comprise the major portion of honey and proteins that include a number of enzymes, and eighteen free amino acids, a carboxylic acid group, of which the most abundant is proline. With respect to carbohydrates, honey is mainly fructose (about 38.5%) and glucose (about 31.0%). Honey contains trace amounts of several vitamins and minerals. Honey also contains tiny amounts of several compounds thought to function as antioxidants, including chrysin, pinobanksin, vitamin C, catalase, and pinocembrin.

Honey use and production has a long history. In many cultures, honey has associations that go beyond its use as a food. Honey is frequently a symbol of sweetness. In Ancient Egypt, honey was used to sweeten cakes and biscuits and was used in many other dishes. Ancient literatures mention the use of honey as a great medicinal and health food. For at least 2700 years, honey has been used by humans to treat a variety of ailments through topical application. It was used as an ointment for rashes and burns and used to help soothe sore throats when no other medicinal practices were available. As an antimicrobial agent, honey may have the potential for treating a variety of ailments. Antibacterial properties of honey are the result of the hydrogen peroxide effect and high acidity.

Physical and Chemical Characteristics of Honey

a. Viscosity: Freshly extracted honey is a viscous liquid. Its viscosity depends on a large variety of substances and therefore varies with its composition and particularly with its water content. Viscosity is an important technical parameter during honey processing, because it reduces honey flow during extraction, pumping, settling, filtration, mixing and bottling. Raising the temperature of honey lowers its viscosity a phenomenon widely exploited during industrial honey processing.

b. Density: Another physical characteristic of practical importance is density. Honey density, expressed as specific gravity, is greater than water density, but it also depends on the water content of the honey [11]. Because of the variation in density it is sometimes possible to observe distinct stratification of honey in large storage tanks. The high water content (less dense) honey settles above the denser, drier honey.

c. Hygroscopicity: The strong hygroscopic character of honey is important both in processing, storage and for final use. Because of this character it easily absorbs moisture from the air. Thus, in areas with a very high humidity it can be difficult to produce good quality honey of sufficiently low water content, which can be measured using a gauge called refractometer. Different researches show that normal honey with a water content of less than 18.3% or less will absorb moisture from the air if a relative humidity is above 60%. The moisture content of honey should not be more than 20%.

d. Color: The other physical characteristics is color and in liquid honey it varies from clear and colorless (like water) to dark amber or black categories which do not really have any bearing on quality. While it is not an indicator of honey quality and there are exceptions to the rule, generally speaking, the darker color the honey, the higher its mineral contents, the pH readings, and the aroma/flavor levels. Minerals such as potassium, chlorine, sulfur, iron, manganese, magnesium, and sodium have been found to be much higher in darker honeys.

e. Crystallization: According to, crystallization is another important characteristic for honey marketing, though not for price determination. In temperate climates most honeys crystallize at normal storage temperatures. This is due to the fact that honey is an oversaturated sugar solution, i.e. it contains more sugar than can remain in solution. Many consumers still think that if honey has crystallized it has gone bad or has been adulterated with sugar. The crystallization results from the formation of monohydrate glucose crystals, which vary in number, shape, dimension and quality with the honey composition and storage conditions. The lower the water and the higher the glucose content of honey, the faster the crystallization. Temperature is important, since above 25°C and below 5°C virtually no crystallization occurs. Around 14°C is the optimum temperature for fast crystallization, but also the presence of solid particles (e.g. pollen grains) and slow stirring result in quicker crystallization.

f. Hydroxyl-methyl-furfural (HMF): Hydroxyl-methyl-furfural is a break-down product of fructose (one of the main sugars in honey) formed slowly during storage and very quickly when honey is heated. The amount of HMF present in honey is therefore used as a guide to storage length and the amount of heating which has taken place. Virtually HMF absent in newly produced honey; it is a byproduct of fructose decay, formed during storage or during heating [12]. Thus, its presence is considered as the main indicator of honey deterioration.

g. PH and Free Acidity: Honey pH depends on both the ionized acids of this food and mineral elements and influences microorganism's development, enzymatic activity and texture. Honey typically has a pH in the range of 3.3–5.6. The natural acidity of honey inhibits growth of many pathogenic bacteria whose minimum tolerated pH is in the range of 4.0–4.5. These two properties of honey can influence honey stability and its storage conditions and also they give some information on honey origin. The high acidity of honey is an indication of the fermentation of sugars present in the honey into organic acid particularly the gluconic acid and the inorganic ions such as phosphate and chloride. According to these honey fermentation results are responsible for two important characteristics of honey: flavor and stability against microbial spoilage. The acidity of honey developed due to the presence of organic acids. The value of honeys acidity, lower than 50 meq/kg of honey, means that honeys will not be fermented. Generally, Chemical composition of honey mainly depends on the vegetation sources from which it derives, though external factors like climate, harvesting conditions and storage can also influence it. Careless handling of honey can reduce its quality. Amongst the factors that most influence quality is high temperature, length of storage and moisture content greater than 21%. They lead to

fermentation, high levels of HMF, loss of enzymatic activity, changes in flavor, darkening and microbial growth.

Melissopalynology

Melissopalynology is the branch of palynology which deals with the study of the botanical and geographical origin of honey by analyzing honey sediments such as pollen, spores and other fungal spores contained in honey samples during microscopic analysis. Pollen grains of each plant species, besides having its own genetic code of inheritance, have special structural patterns, which enable us to differentiate pollen grains of one species from another. In this regard pollen analysis is the essential tools in the analyses of honey and used to indicate floral nectar sources utilized by bees to produce honey. Moreover, the relative pollen frequency in honey is used to verify and label a honey sample as to the major and minor nectar sources [13]. This information has important commercial value because honey requires certain types of verification and it must be correctly labeled before marketed. This is because honey made from some plants commands a premium price and honey-producing nations of the world require accurate labeling of honey before it can be sold. This is especially true for the European Union that has strict labeling regulations for honey products

Pollen analysis of honey is also of great importance for quality control and helps to ascertain whether honey is adulterated or not. Honey adulteration is also serious problems in all over the world including Ethiopia. Adulteration of honey with table sugar is a common practice by honey traders (Table 1). Moreover, agricultural expansion, growing of monoculture crops and industrial pollution together with pesticide application is serious threat for exporting honey as organic products to the International markets. Mellissopalynological information is also important to confirm poisonous cases and to take appropriate measures like to avoid beekeeping in area where high population of poisonous plants or grow other bee forages that can flower in the same period to dilute the poisoning cases.

Materials and Methods

Location and description of the study area

The study was conducted at Gemachis forest in Oromia region and located in West Hargrge zone 6.5 km from district town, Kuni and 332.5 km from Addis Ababa. The altitude ranges from 2,118 and 3,017 masl. The district has bi-modal rainfall distribution with small rains starting from March/April to May and the main rainy season extending from June to September/October. The minimum and maximum temperature 15°C and 30°C with the average temperature is 22°C.

Gemechis forest belongs to dry afromonatne vegetation of which *Croton macrostachyus, Vernonia amygdalina* and *Hagenia abysinica* are some of the major species occurring in the forest and Juniperus *procera, Podocarpus falcatus* are introduced through plantation activities to enrich the vegetation (Western Hararghe Zone Forest and Wildlife protection Enterprise office.

The forest is demarcated as community forest in 1996 E.C and around 550 bee colonies is placed in it. From the total colonies about 500 is traditional and 50 of them are frame hive occupied with bee colonies. Around three beekeepers' association and one forest, enterprise is investing in Gemachis forest (Figure 1).

Method of data collection

a. Reconnaissance: Reconnaissance survey was conducted to become familiar with the area, to get an insight on the vegetation distribution in the landscape, to observe and locate the possible transect during the actual study. Stratified random sampling procedure was followed to select the representative sites based on the altitudinal strata prior to the survey.

b. Sampling technique: Stratified sampling technique was followed based on altitudinal range [14].

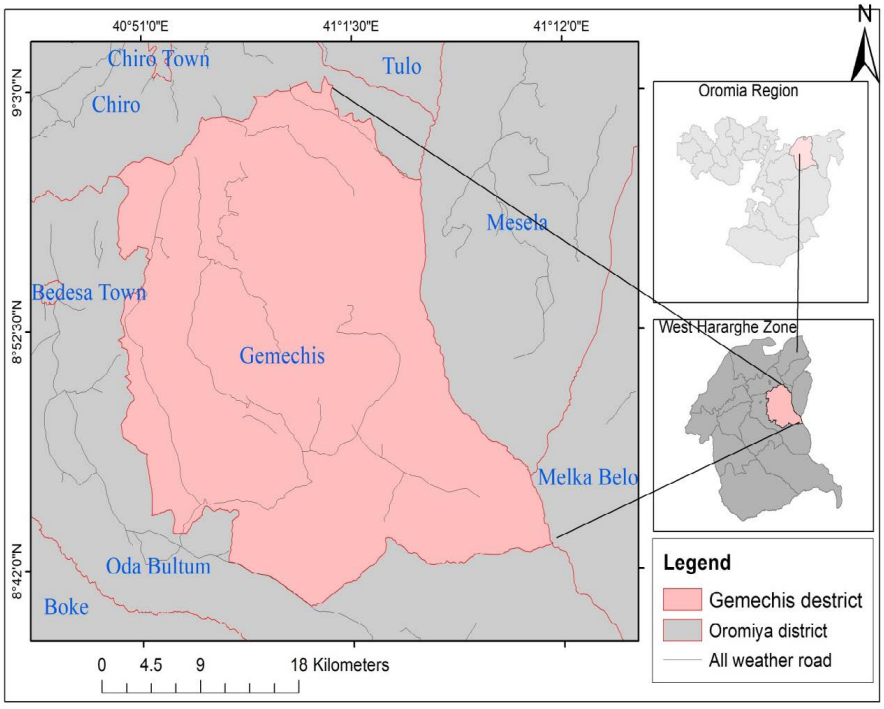

Figure 1: Location map of Gemechis district.

Data collections and recordings

Household survey for Honey production system

A purposive sampling technique was employed to select districts, kebeles and beekeepers owing minimum five honeybee colonies. Two kebeles were selected from the study district bordering Gemachis Forest. A total of 29 beekeeper's respondents were selected from two kebeles surrounding the forest for the household survey using the total enumeration or census. The questionnaire was prepared and pre-tested before interrogating and some re-arrangements, reframing and corrections in accordance with respondents' perception. Model beekeepers and beekeeper's associations living around the forest were selected purposively to assess the honey production system and contribution of forest beekeeping for income generation. The primary data were covered beekeeping management practices, honey production practice, honey yield, annual honey production, income from beekeeping, livestock, crops and others in the forest, honey harvesting period, bee floral resources, constraints of forest beekeeping in the area and conservation mechanism for beekeeping.

Focus group discussion: In each study sites discussions were under taken with livestock development agents, elders, village leaders and individuals who have knowledge about the beekeeping practices, management systems, honeybee flora, and constraints of beekeeping practice in the area. Focus group discussions consisting of eight knowledgeable individuals to complement the survey work and the researcher were facilitated the discussions at each site. Individuals for focus group discussions were focused on beekeeping activity, knowledge about the major bee flora, beehive types, honey storage, colony management practice, agro- chemical application concept, honey utilization and major opportunities and constraints of beekeeping practice.

Secondary sources: Previous studies, guidelines, manuals and documented data were used to review, characterize of the beekeeping production system and performance evaluation of different hive types in different agro-ecologies. The secondary data was collected from published and unpublished documents of government and NGOs, Journals, Magazines and Administrative reports which were related to data about the title.

Bee forage data collection

Field observation

Plants visited by honeybees were observed during flowering period of major bee forages in various sites of the study forest. During observations, the types of food source offered by plants and the behavior of the honeybees while collecting nectar and pollen were noted. Activities were observed including insertion of the proboscis to the corolla of flowers and the "pumping" movement of the abdomen when they are sucking the nectar. The flowering periods of plants that bee forages on was recorded. Data records include dates of blooming and shedding of flowers that was visited by the local honeybees.

Bee forage inventory

To assess the bee forages abundance and diversity, four transect lines were laid out from apiary sites to North, South, West and East within 2 km radius following GPS. Apiary sites were sampled systematically after 2 km distance from one to the other in order to avoid redundancy. Along these transects plots of 20x20 m were laid out within 400 m interval between the sample plots. In order to retain accuracy [15], five (5) small plots measuring 2x2 m were laid out within the larger plot to capture herbs and grasses. All the plant species encountered in each sample plots were recorded and percentage cover of each species was estimated visually. Moreover, growth forms of the plants (trees, shrubs and herbs) was recorded as when the height of plants exceeds 3 m considered as trees, as shrubs when they attained a total height of 1-3m and plants below 1m were considered as undergrowth or herbs in transects. Bee forage specimens was collected, pressed and dried and identified at Holeta Bee Research center using the account of Flora of Ethiopia and Eritrea (FEE) and Honeybee flora of Ethiopia.

Data Analyses

Data processing which includes manual editing, coding, data entry, data cleaning and consistency checking were made before undertaking analysis. Descriptive statistical tools were used to analyze the collected data including frequency, percentages, mean and, standard deviation were computed to analyze and compare the quality parameters of honey samples at different locations (highland, midland, Lowland and local market), SPSS software (version 20) was applied at the significance level of 0.05

Results and Discussions

Socioeconomic Characteristics of Respondents

The present investigation revealed that majority of respondents was in the reproductive age group (41.10 years old). Aged persons as old as 70 years were also involved in beekeeping activities (Table 2).Reported an average of 42.03 years old for beekeepers in Southern Ethiopia [16]. The results of our investigation were also in line with which states that beekeeping has an advantage of being practiced by aged men and persons with disabilities. The average land holding was 0.33 ha per household which is less than the national average of 1.17 ha per household. The long beekeeping experience in the study area was 30 years old and minimum was 1 years old.

Educational Status and Sex of the Respondents

Regarding educational status of households, 24.1% of respondents never attained any formal education whereas 31.0% of respondents completed elementary school (Table 3). From the sample respondents

Table 1: Altitudinal stratification of Gemachis forest.

No.	Agro ecology	Altitude (masl)	No. of the plots	Proportion
1	Lowland	2118	12	33.3%
2	Midland	2118-2567.5	12	33.3%
3	Highland	2567.5-3017	12	33.3%
Total plots			36	100%

Table 2: Average Age, Beekeeping Experience and Land Holding of the Sample Respondents in the Study Area.

	N	Minimum	Maximum	Mean	Std. Deviation
Age of the respondent	29	25	70	41.1034	11.23561
Beekeeping experience	29	1	30	11.2414	7.77659
Land size	29	0.025	0.75	0.33	0.158

Table 3: Sex and Education Status of the Respondents.

Variables		Frequency	Percent
Education status	Illiterate	7	24.1
	Read & Write	12	41.4
	Elementary	9	31
Sex	Male	21	72.4
	Female	8	27.6

27.6% were female and 72.4% male. The result showed unequal participation of males and females in bee keeping activities. It agrees with the findings who reported low level of females' participation in beekeeping activities in Ethiopia.

Beekeeping Practice in Gemachis Forest

Farmers in the study area observed to use three different types of beehives (Table 4) for honey production. The result of the study showed that 82.8%, 13.8% and 3.4% of the respondents owned traditional, both traditional and movable frame beehives and frame hives respectively. It is found that majority of the beekeepers depends on traditional honey production systems characterized by low productivity. The result corresponds to previous studies conducted in the northern, south western and central parts of Ethiopia. A similar result was also reported from Tanzania where 99% of the hives owned by the farmers were traditional ones. In addition, 75.86% of the respondents use *Arundo donax* to construct traditional hive.

Honey Production Trend in the Study Area

The present investigation revealed an average honey yield per annual per hive type were 35.84 kg, 30 kg, 77.75 kg for traditional, transitional and moveable frame hives, respectively in 2018. Movable frame hives were more productive followed by traditional and transitional beehives. In 2019 the yield was 40.23 kg and 43.33 kg for traditional and moveable hives respectively and no one owned transitional hive in this year (Figure 2). In 2020, 15.80 kg and 19.66 kg for traditional and moveable frame hive respectively. The results showed that the honey yields were decreasing from year to year due to unknown reason which might be due to honey bee enemies and pesticides. The similar results were reported by.

Identification of Honeybee Flora and Their Flowering Calendar

The flowering time of common bee flora species identified in the study area was indicated in (Table 5). According to field observation and inventory of bee forages 33% plant species flower during September-November, 13% during December to February, 38% during March to May and 17% of plants during June to August (Table 6).

Among the identified bee forages *Guizotia spp, Bidens spp, Cordia africana, Croton macrostachyus, Acacia spp, Vernonaia amygdalina, Eucalyptus camalduensis, Eucalyptus globulus, Maesa lanceolata, and Coffea arabica* were used as important bee floras contributing for honey production during harvesting periods of Oct-Jan. The contribution of the species as major source of honey is due to abundance and as potential source of nectar and pollen for honeybees. This is agreeing with reported that, *Cordia africana, Croton macrostachyus, Acacia senegal, Vernonaia amygdalina, Eucalyptus camalduensis, Combretum molle, Albizia schimperiana, Aningeria altissma, Syzygium guineense, and Coffea arabica are* the major bee forages of Ethiopia. The major honey flow season of the study area was from Oct-Jan and the minor flow season is from April-May depending on the availability of bee forage that in return depends on the intensity of rain fall. However, the major bee plants in state of decline in the study area due to expansion of agriculture and investment intervention [17].

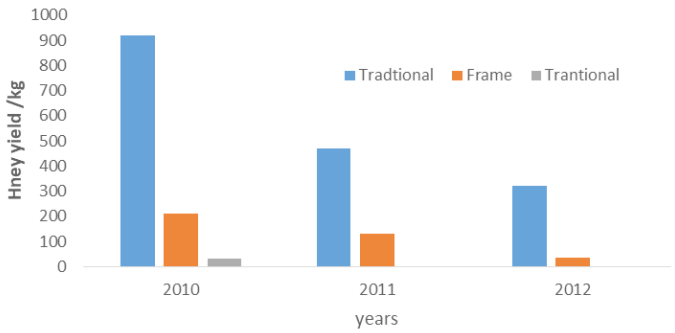

Figure 2: Honey Yield Trend for Last Three Years from Different Bee Hives.

Table 4: Types of Hives Owned by the Beekeepers.

Hive type	Frequency	Percent
Traditional	24	82.8
Frame Hive	1	3.4
Traditional and frame hive	4	13.8
Total	**29**	**100**

The presence of higher number of flowering plant species during September to November is due to availability of moisture following the main rainy season which lasts from June to August. This is in agreement with who reported that the majority of bee plants flower after the summer rain starting from Jun to early September. The major honey flow period in the study forest occurred during October- January. The major bee forages flowering during from September to October were *Guizotia scabra, Eucalyptus Camalduensis,* and *Eucalyptus globulus.* On the other hand, *Vernonia amygdalina, and Maesa lanceolata* commonly flower from January to February due to their adaption under low moisture regime and; *Eucalyptus Camalduensis*, *Croton maycrostachys, Coffee arabica, and podocarpus falcatus* commonly flower from March -May. This result is similar with the previous studies conducted in Oromia and Amhara regional state respectively. In addition, *Eucalyptus camaldulensis and Eucalyptus globulus* flower all year round provide continuous supply of nectar and pollen to honeybees. This is agreeing with the previous studies indicated that *Eucalyptus camaldulensis*, *Datura arborea, Plantago lanceolata* flower throughout year. The flowering time *of Cordia africana and Zea mays* was from June-August. This is similar to the previous study by and in Kilte-Awlaelo and Burie district. The variation of flowering period between different plant species is due to variation in climate, topography and availability of moisture in the soil. This in agreement with who noted that the flowering time of bee flora may differ from one place to another due to variation topography, climate and farming practices. Following the flowering period two honey flow season was reported in the area. The first honey harvesting starts at mid-November and lasts early December whereas the second honey flow season started during May to June after small rainy season. Relatively low number of species flower during dry period (December to February) and rainy season (June-July) due to extended dry period and heavy rainfall. During dry season (January to February) beekeepers feed their honeybee colonies using local available feed resources (Shuro, Berbere and Maize flour).

Major Constraints of Honey Production in the Area

The major problems of beekeeping reported in the area were honeybee enemies, pesticides, honeybee disease and drought. However, majority of the respondents have reported that pesticide and honeybee enemies are the major constraints in the area. Among the enemies of honeybee's ants are serious problems. Agro-chemicals poisoning are agricultural inputs that used to control weeds, pests and fungus to increase crops production and productivity. The farmers around Gemachis district predominantly produce maize, khat, misir and horticultural crops. The main agricultural chemicals that are used by the beekeepers as well as by the farmers in the study area were DDT and 2,4D (two four D). These agro-chemicals were directly or indirectly affect the life of honeybees or beekeeping sub-sector.

Table 5: Identified Bee Flora Species via Social Survey.

No	Local Name	Scientific Name	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Abayi	Maesa lanceolata												
2	Acacia	Acacia spp												
3	Bakkaniisaa	Croton macrostachys												
4	Bargamoo Diimaa	Eucalyptus camaldulensis												
5	Bargamoo Adii	Eucalyptus globulus												
6	Boqolloo	Zea mays												
7	Boroddoo	Myrica salicifolia												
8	Buna	Coffea arabica												
9	Dannisa	Dombeya torrida												
10	Eebicha	Vernonia amygdalina												
11	Ejersa	Olea europaea L. ssp. Cuspidate												
12	Giishxaa	Annona reticulata												
13	Giraaviliyaa	Grevillea robusta												
14	Goraa	Rosa abyssinica												
15	Hadaa	Guizotia scabra												
16	Handode	Phytolacca dodecandra												
17	Hanquu	Embelia schimperi												
18	Heexoo	Hageniaia abyssinica												
19	Koshommi	Dovyalis caffra												
20	Mixoo	Rytigna neglecta												
21	Qaxammee	Maytenus sp.												
22	Wadeessa	Cordia africana												
23	Xaxessa	Allophylus rubifolius												

Table 6: Major Constraints of Honey Production System in the Study Forest.

No	Constraints	Sum	Index	Rank
1	Honeybee disease	55	0.185	3
2	Honeybee enemies	58	0.19	2
3	Pesticides	70	0.23	1
4	High temp	9	0.030	8
5	Shortage of forage	30	0.10	5
6	Drought	36	0.120	4
7	Absconding	16	0.054	7
8	Shortage if training	24	0.08	6
9	Absence of good market	0	0	9

Table 7: Total Annual Income from Crop, Livestock and Beekeeping.

	N	Minimum	Maximum	Mean	Std. Deviation
Total income from crop	29	2000	60000	9912.75	10950.94
Total income from live stock	29	840	144000	16388.41	27155.18
Total income from beekeeping	29	1000	30000	7601.75	6247.36

Total Annual income from Crop, Livestock and Beekeeping

The average annual income of the households from crop, livestock and beekeeping were 9912.75, 16388.41 and 7601.75 Ethiopian Birr respectively. The income obtained from beekeeping used to pay government tax, school fee and house hold items as indicated in (Table 7).

Poisonous Bee Floras

According to beekeepers' report, *Caesalpinia decapetala*, *old vernonia spp*, *Nicotina tabacum* and *C. macrostachyus* were reported as poisonous honeybee plants. Out of the respondents 62% mentioned *Croton macrostachyus* as poisonous honeybee plants. The result is in agreement with where *C. macrostachyus* known to cause honeybee death after completion of its flower in kaffa and sheka zone of south Ethiopia.

Bee Forage Inventory

According to plant inventory, field observation and pollen analysis of honey Forty-eight (48) honeybee plant species were identified; belonging to 33 families of which Fabaceae, Roseaceae and Verbenaceae were the most frequent families in the study area. These results are comparable to who reported that fifty-eight plant species in 34 families were identified being visited by honeybees that were collecting either pollen or nectar or both in Menagesha suba state forest. Furthermore, also reported that Asteraceae, Leguminosae, Lamiaceae, Acanthaceae, Malvaceae, Poaceae, Euphorbiaceae, and Myrtaceae are the major bee forages families (Appendix1). These include shrub (54.1%), tree (16.6%) and herbs (29.1%) (Figure 3). Similar results were also reported by with herbs, trees, shrubs being source of forage for the bees. The highest shrub population in the area is might be due to fast regeneration of

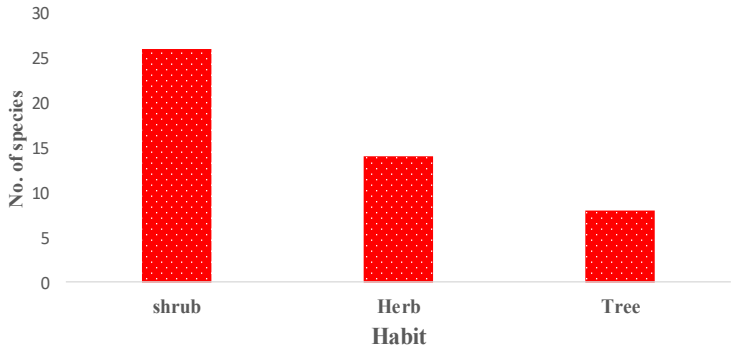

Figure 3: Habit of the Plant.

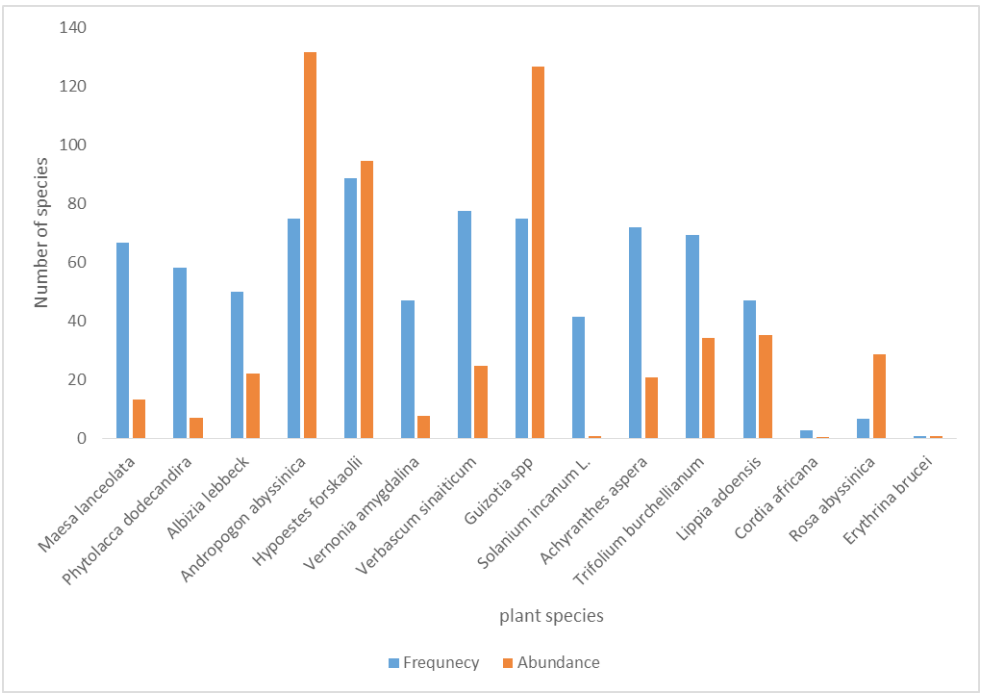

Figure 4: Honeybee flora species abundance and frequency of Gemachis forest.

woody plants or selective cutting of big trees [18]. Furthermore, the Gemachis forest is one of the protected forest and less disturbed by the surrounding communities. This is in agreement with who reported that the woody plant population is relatively higher than trees and herbs.

Bee Flora Species Abundance and Diversity

The abundance of bee flora species in the study area was calculated based on the data collected during plant inventory (Appendix 2). Accordingly, *Solanium spp*, *Andropogon abyssinica, Guizotia spp* and *Hypoestes forskaolii* were the most abundant bee flora species in the study area (Figure 4). On the other hand, *Cordia africana, Rosa abyssinica* and *Erythrina brucei* were the least abundant bee flora species in the study area. The higher frequency and abundance of the species might be attributed to occurrence of plant species at wide range of altitude, seed dispersal capacity, germination vigor and resistant to pests and pathogen are some of the factors contributing for the higher frequency and abundance of bee forages in the area.

Bee Flora Species Diversity in Relation to Agro-Ecology

The Shannon diversity indices for the common bee flora species in the study area was calculated (Table 8). Accordingly, bee flora species diversity at Sororo site (lowland) (2.619) was relatively higher than both Chafe Kebena (midland) (2.377) and Arer (highland) (2.541). In this study species richness (S) was computed as, the observed number of bee flora species for each agro ecology (Table 8). As a result, the number of species observed in Chafe Kebena and Sororo site was the same. The Shannon diversity indices for the common bee flora species in the study area were calculated and there was no significance difference between different sites. This is due to similarity of agro-ecology, species composition and seed dispersal by different agents of pollination to the agent sites which make low species diversity and higher number of common species.

Bee Flora Species Jaccard's Similarity along the Altitude

The result showed that there was no species difference among the three sites of the forest (Table 9). But there was difference between Sororo and Arer site (41. 88%). As a rule, if the similarity index is greater than 50% the two sites are similar.

Table 8: Shannon Diversity Index for Bee Flora Species in Gemechis Forest.

	Sites		
Bee flora species diversity index	**Chafe kebena**	**Sororo**	**Arer**
Number of individual (N)	6905	7251	5182
Observed number of species (S)	46	46	31
Shannon diversity (H')	2.377	2.619	2.541
Shannon evenness (E)	0.62	0.68	0.74

Table 9: Similarity index for bee flora species in Gemachis forest.

Sites	# of individuals common to the sites	#of individuals unique to the sites	Similarity index
Chafe kebena		291	
Sororo		487	
Arer		745	
Chafe Kebena and Sororo	1432		64.79%
Chafe Kebena and Arer	1874		64.90%
Sororo and Arer	888		41.88%
Chafe Kebena, Sororo and Arer	13307		89.73%

Table 10: Pollen Analysis Results for each Agro ecology in the Study Area.

Honey sample code	Agro ecology	Dominant pollen type	Minor pollen type
Arer	Highland	Bidens pachyloma (75.90%), Mesea lanceolata (6%)	Calpurnia subbecondra (4.62%), Guizotia abyssinica (3.96%), Justica heterocarpa (2.64%), Vernonia spp (1.98%), Zea maize (1.98%), Dombeya torrida (0.13%), Plantago lanceolata (0.53%), Eucalyptus globulus (1.65%)
Chafe kebena	Midland	Eucalyptus globulus(54.93%),Guizotia abyssinica (21.84%),Maesa lanceolata (12.60%)	Lapidium sativum (1.75%), Cirium schiperi (1.25%) Syzygium guineense (1.87%), Hypoestes trifolia (0.94), Vernonia adoensis (0.62%), Bidens pachyloma (3.12%),Plantago lanceolata (0.49%),Rumex nervosus (0.56), Syzygium guineense (0.52%)
Sororo	Lowland	Eucalyptus globulus (53.31), Guizotia abyssinica	Brassica carinata (1.30%), Maesa lanceolata (2.56%), Bidens pachyloma

Pollen Analysis of Honey Samples of Gemachis Forest

Pollen analysis is also known as *Melissopalynology* is valuable tool for the identification of the botanical and geographical origin of honey sample. These pollen analytical studies provide information of resources of bee. The honey samples were collected from different sites of Gemachis forest. The total pollen count was expressed in pollen percentage frequency (PPF) based on the qualitative analysis. As indicated in (Table 10), the present investigation on the basis of pollen percentage showed that multifloral pollen belongs to the family Asteraceae, Acanthaceae, Rosaceae and monofloral pollen belonging to the family Asteraceae and Myrtaceae.

Based on honey pollen analysis 19 plants species were identified as honey bee plants. Monofloral honey is where the bees have been foraging predominantly on one type of plant, and is named according to that plant. As the result of pollen analysis of honey, two types of monofloral honey types were identified in the area and their relative pollen count for species contributing for monofloral honey were indicated in (Figures 5 and 6). *Guizotia spp and Eucalyptus globulus* were major monofloral honey types identified comprising 74.9% and 54.9% pollen count respectively. The total number of plant species of pollen grains contributing for monofloral honey of *Guizotia* spp comprised 10 species of bee forages followed by *Eucalyptus globulus* with 11 species. According to the social survey the following monofloral honeys were listed: *Vernonia honey, Bidens honey and Cordia africana honey*. Accordingly, 41.38%, 13.79%, 6.89% of the respondent answered *Vernnonia honey, Bidens honey and Cordia africana* respectively. The rest of the respondents answered they do not know monofloral honey. There is mismatch between survey and pollen analysis regarding monofloral honey indicating there is knowledge gap between beekeepers.

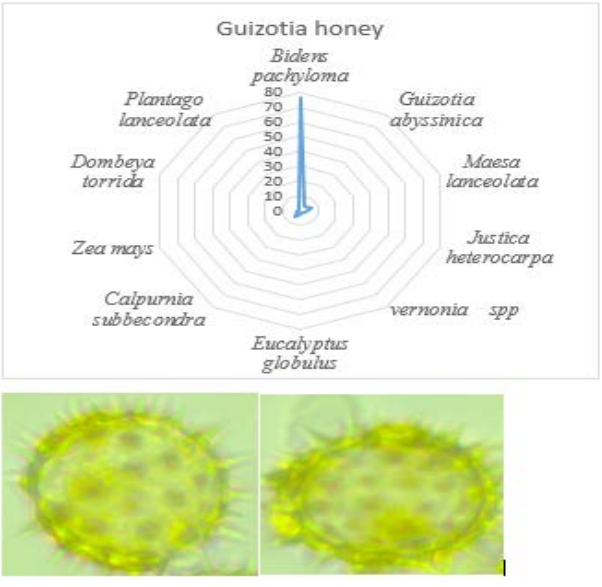

Figure 5: Contributing Species for Guizotia spp honey from Arer site.

Monofloral honey is where the bees have been foraging predominantly on one type of plant, and is named according to that plant. As the result of pollen analysis of honey, two types of monofloral honey types were identified in the area and their relative pollen count for species contributing for monofloral honey. The dominance of pollen from the *Guizotia spp* and *Eucalyptus globulus* can be attributed to widespread distribution in the area and high pollen and nectar potential of the plants. This finding is in agreement with *Eucalyptus globulus* and

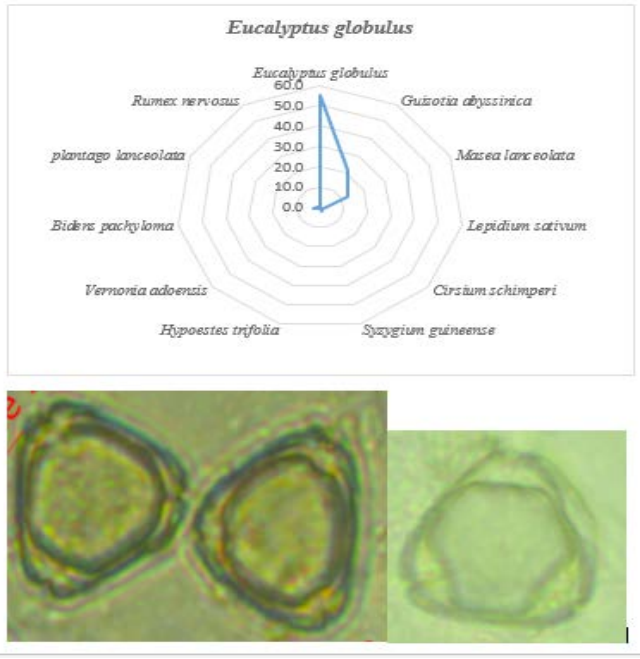

Figure 6: Contributing Species for Eucalyptus globulus Honey for Sororo site.

Guizotia scabra are one of the potential monofloral honey source plants in Borena zone of Ormoia.

Honey Quality Analysis

Honey from Gemachis forest was studied based on physicochemical properties. Moisture content for all samples was high, with an average value of 19.8% (Table 11). The average free acidity values obtained were 34.6, 36.9 and 11.2 meq kg-1 for honeys from Chafe kebena, Sororo and Arer sites respectively (Table 12). The highest pH values were obtained for honeys from Sororo site, while the lowest values were registered in honeys from Arer site (Table 12). All the samples had very low ash values, ranged from 0.40 to 0.50%. The average amount of HMF was very low for all the samples (Table 13). These result of the current study were in line with accepted range by the international regulations for honey quality (Codex Alimentations, 2001), (Council Directive of the European Union, 2001) and by the (Ethiopian honey quality standards, 2005).

The honey quality analysis results are in agreement with International honey quality requirements. The mean moisture contents of honey samples collected from different altitudes of Gemachis forest is 19.8% with standard deviation of ±2.19. After the carbohydrates, water is the second most important component of honey. Moisture content of honey substantially affects some physical properties of honey (crystallization, viscosity, specific weight) and climatic factors

Table 11: Physicochemical Parameters of Apis Mellifera L. Honey Samples from Gemachis Forest.

Parameters	Minimum	Maximum	Mean	Std. Deviation
Moisture Content	18.2	22.3	19.8	2.19
PH	4	4.7	4.37	0.35
Free Acidity	11.2	36.9	27.67	14.22
Ash Content	0.4	0.5	0.47	0.057
Hydroxyethylfurfural	0.7	11	6.07	5.16

Table 12: Physicochemical Characteristics of Honey Samples from the Three Agro Ecologies of Gemachis Forest.

Study Site		Moisture %	PH	Free Acidity (meq/kg)	Ash Content (%)	Hydroxymethylfurfural (mg/kg)
Arer	Mean	22.3	4	11.2	0.5	6.5
	Minimum	22.3	4	11.2	0.56	6.5
	Maximum	22.6	4	11.2	0.5	6.5
Chafe Kebene	Mean	18.9	4.4	34.6	0.5	11
	Minimum	18.9	4.4	34.6	0.5	11
	Maximum	18.9	4.4	34.6	0.5	11
Sororo	Mean	18.2	4.7	36.9	0.4	0.7
	Minimum	18.2	4.7	36.9	0.4	0.7
	Maximum	18.2	4.7	36.9	0.4	0.7
Total	**Mean**	**19.80±2.19**	**4.36±0.35**	**27.56±14.2**	**0.46±0.05**	**6.06±0.5.16**
	Minimum	**18.2**	**4**	**11.2**	**0.4**	**0.7**
	Maximum	**22.3**	**4.7**	**36.9**	**0.5**	**11**

Table 13: Comparison of Physic-Chemical Properties of the Study Areas Honey with National and International Standards.

Parameters	Mean ±SD	Range	National average	Range values	National	International acceptable level(IHC, 2002)
	(current study)				acceptable level	
Moisture content	19.8	22.3-22.6	21	15-32	Max. 21	Max. 20
Ash	0.46	0.40-0.56	0.23	0.01_12	Max. 0.6	Max. 0.6
HMF	6.06	0.6 - 11	32.4	0.96-96	Max. 40	Max. 60
Acidity	27.56	11.2 - 36.9	39.9	17-95	Max. 40	Max. 50
pH	4.36	4-4.7				

(humidity and air temperature in the hive), processing and storage conditions as well as by the honey plant species [19]. The result is in congruent with the report of who reported the moisture content of honey of Guji zone ranges between 15 and 23%. The higher moisture content in honey is also caused by yeast that cause honey to ferment and change the flavor. However, there are no substantial differences in water content between individual honey samples of Gemachis forest due to similar agro-ecology and microclimate of the area.

The minimum, maximum and mean ash contents of the honey samples analyzed in the present study was lower than the maximum limits (0.6%) set for ash content of the honey by EU, CA and QSAE and the average was within the national and international limits for ash content of honey.

Ash content of all samples was within the range (0.1 to 0.6 g/100 g) accepted by Codex range (Codex Alimentations, 2001). The ash contents observed in this study are higher than that who reported mean ash values of 0.14 and 0.23% for Sekota district and Ethiopia, respectively. In general, the overall mean ash content (0.46±0.05) observed in the present study indicating honey from the study area is full fill the standard quality but it was relatively lower and is within the accepted range of national and international standards.

The overall means free acidity of honey samples analyzed was 27.57% which is within the acceptable limits (≤ 40 meq/kg) set by QSAE and CAC, whereas the limit for honey acidity according to (EU, 2002) honey standard is≤ 50 m eq/kg. This result revealed that the freshness of honey samples and absence of unwanted honey fermentation where harvesting time and storage condition are the matter. None of the samples exceeded the limit set, which may be taken as indicative of freshness of all the honey samples of the study area. Variation in free acidity among different honeys can be attributed to floral origin or to variation in the harvest season. The lowest acidity value was found in honeys from Arer site. The mean acidity value observed for Gemachis forest honeys (27.57meq kg-1) was similar with results obtained in Tigray (29.89meq kg-1), North Western part of Amhara, (28.24 meq kg-1) and South west (28.32 meq kg-1) regions of Ethiopia.

Regarding the pH, honey is naturally highly acidic. Its pH is extremely low, ranging between 3 and 4.5, which inhibits the growth of bacteria and other spoil-ready organisms. PH of honey samples in the current study ranged from 4.00 to 4.70, with an average value of 4.37 which reveal honey is quality enough for long time storage. The low pH of honey inhibits the presence and growth of micro-organisms and makes honey compatible with many food products in terms of pH and acidity. Samples from Chafe Kebena had the highest records. The values obtained for Arer site were slightly lower than the results obtained for honeys from the other studied sites.

The HMF values ranged from 0.70 to 11.00 mg kg-1, showing a HMF level very much lower than 40 mg kg-1, maximum value proved satisfactory in international standards. These low values may be attributed to the climatic conditions of Gemachis forest. The HMF range of this study was in line with the International and National limits set by. The low HMF content of the study area's honey indicates that the honey is fresh, unheated and free of adulteration. In Ethiopia, the acceptable HMF level is below 40 mg/kg on the other hand the HMF value of study area was less 40 mg/kg. This is agreeing with test result of Ethiopia reported as 32.4 mg/kg , 38.55 mg/kg in Tigray, 6.32 mg/kg in Gera district in Oromia region [20].

Conclusions and Recommendations

Conclusions

This study was conducted from October 2019 to November 2020 with the main objectives of Assessment of Honey Production System, Bee Forage Diversity and Honey Quality of Gemachis Forest. Availabilities of bee floras are very critical for the establishment of an apiary sites. Adequate knowledge of beekeepers in identification of bee flora and flowering time play an important role in apiculture development and honey production system. Gemachis forest is suitable for beekeeping activity as it is endowed with various agro climatic conditions and diversified honeybee flora species which attract honey bees. As the result of this study, 48 plant species belonging to 33 families were identified during bee flora inventory of which Fabaceae, Roseaceae Verbenaceae and Asteraceae are with higher number bee forages.

The pollen analysis of honey indicated that 19 plant species were identified of which *Guizotia spp, Eucalyptus globulus* and *Bidens pachyloma* are dominant honey source plants in the area and the remaining plant bee forages are minor due to limited species density, low nectar and pollen yielding potential of the plants.

The dominance of pollen from the *Bidens pachyloma*, *Eucalyptus globulus* and *Guizotia scabra* can be attributed to widespread distribution in the area and high pollen and nectar potential of the plants

Physicochemical analysis of honey showed that the mean moisture, acidity, ash and pH contents of the honey samples collected from the study area revealed that, all the physicochemical parameters lay with-in limits of local and international standards set by Quality and Standards Authority of Ethiopia, Codex Alimentarius Commission and EU Council.

Majority (82.8%) of the beekeepers owned traditional hive and only 3.4% of the beekeepers owned moveable frame hives.

Honey yields were decreasing from year to year due to bee enemies, pesticides and deforestation and climate change.

Recommendations

- Beekeepers should utilize the forest for beekeeping activities, because the forest is of good plant diversity
- Intervention of GOs' and NGOs' is paramount to change the very old traditional beekeeping practices through adopting improved technologies and management practices and practical skill trainings.
- Introduction of full package improved beekeeping technologies with adequate practical skill training is required
- Awareness should be given for the beekeepers on other hive products like wax, bee colony, pollen and propolis production and selling
- Market linkage is also recommended because honey from Gemachis forest is found within the national and international quality standards
- Designing effective honeybee enemies and pesticide controlling methods.
- Further research on establishment of flowering calendar and carrying capacity of the Gecmachis forest for beekeeping is highly recommended

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