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Research Article

Honeybee Floral Diversity of Gemachis Forest, West Hararghe Zone, Oromia Regional State, 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 attraction 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 bee floral diversity of the forest. For the inventory of bee forages a transect line were made in three selected altitudinal strata. Honey samples also were obtained from the three agro ecologies of the forest: Arer (high altitude), Chafe kebene (medium altitude) and Sororo (low altitude). The pollen spectrum of the honey was analyzed to determine the botanical and geographical origin of the honey. 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. Thus, beekeepers should conserve the forest for sustainable honey production since the forest is endowed with good honeybee plant diversity.

Keywords

Gemmachis Forest, Bee Forage Diversity, West Hararghe, Shanon Index

1. Introduction

Apiculture is an ancient agricultural practice in Ethiopian farming societies 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 [17]. 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 also 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 diversi-

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fied honeybee flora and huge number of honeybee colonies [34]. On top of this diversified agro- climatic conditions of the country generated suitable environmental conditions for the growth of 6000 to 7000 species of flowering plants of which most of them are bee plants [3]. 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 [13]. Moreover, about 4,601,806 hives exist in Ethiopia out of which about 95.5% are traditional, 4.3% transitional and 0.20% frame hives. Currently, the honey production potential of the country is 500,000 metric tons per annum. However, the recent annual honey production of Ethiopia is only 54,000 metric tons of honey and 5,000 tons of beeswax [3] making one of the 10 top honey producing country in the world and first in Africa and ninth in the world [46].

Beekeeping plays a crucial 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 [15]. For instance, in Kenya, charcoal burning was successfully reduced by introducing beekeeping as an alternative economic activity [36]. 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 [19] 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 [40, 6]. The carrying capacity of the beekeeping is the number of bee colonies it can support which depend on, abundance and 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 [30].

Gemechis mountain forest is one of the remaining patches of forests in West Hararghe zone. According to [42] 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 economic importance for the surrounding community as source of water, fuel wood and habitat for different wild animals. 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.

1.1. Statement of the Problem

Honeybee health depends on forage availability amongst other things with great quantity and quality of the forage [12], 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.

1.2. Specific Objectives

1) To study the bee forage abundance and diversity of Gemachis forest
2) To assess botanical origin of honey

1.3. Research Questions

1) Which bee forages are more abundant and diverse in the study area?
2) What are the major pollen producing plants in the area?
3) Which species of bee forage contributing for monofloral honey production?

2. Literature Review

2.1. 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 widely in south and southwest areas of Ethiopia where there is high vegetation cover and high honeybee colonies [41]. In this case the beekeepers hang several traditional hives on trees in the dense forest mostly, far away from their settlement areas.

2.2. Potential Bee Forage in Ethiopia

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 [2, 22, 24]. 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 [20]. 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 [9]; 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 [2]. According to [33] 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 [1].

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 [4]. About 500 honeybee flora species were identified by the previous study of [20] 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 [20] honeybee plants can be categorized as major and minor source of bee forage.

2.3. Bee Forage and Its Role for Honeybees

According to Gezahagn plants are the food source to honeybees [22]. 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 [5]; 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 [11]. 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 [31]. Based on study conducted by [25] 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* [25] Pollen plants are important in beekeeping, especially at the time of colony build-up [5]. Generally, assessing the potential bee flora and their importance as a major or minor for honeybee plant is very important in seasonal colony management [25]. According to a study conducted in Zaria northern Nigeria, about 57.1% of the bee visited plants are perennials while 42.9% are annuals. [39], noted that many plants produce pollen for the bees, it is usually nectar producing species that are the most interesting for beekeepers.

Study conducted at University of Georgia revealed that in planning a bee pasture it 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 [14].

2.4. Floral Calendar of Honeybee Plants

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 [16]. 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 [28].

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 [11].

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 [20, 43]. In Bure District also the potential bee floras are studied with their flowering calendar by [43], 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 [2].

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 [11].

2.5. 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 [11]. 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 [38]. Hence, apiary site should be near by the good bee forage plants in order to obtain good honeybee products and colony strength [26].

A study conducted by Akratanakul P., also illustrated that in order to survive prospers and is 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 [5].

Previous study in Ibadan (south west of Nigeria) by [31] 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 [11] 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 [10].

Liseki, S. and Boniphace, T. also explained that the best harvesting period should be before the start of the dearth period when few plants are flowering. 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 [28].

3. Materials and Methods

3.1. Location and Description of the Study Area

The study was done at Gemachis forest in Oromia regional state and the forest 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 ℃ and 30 ℃ with the average temperature is 22 ℃ [42].

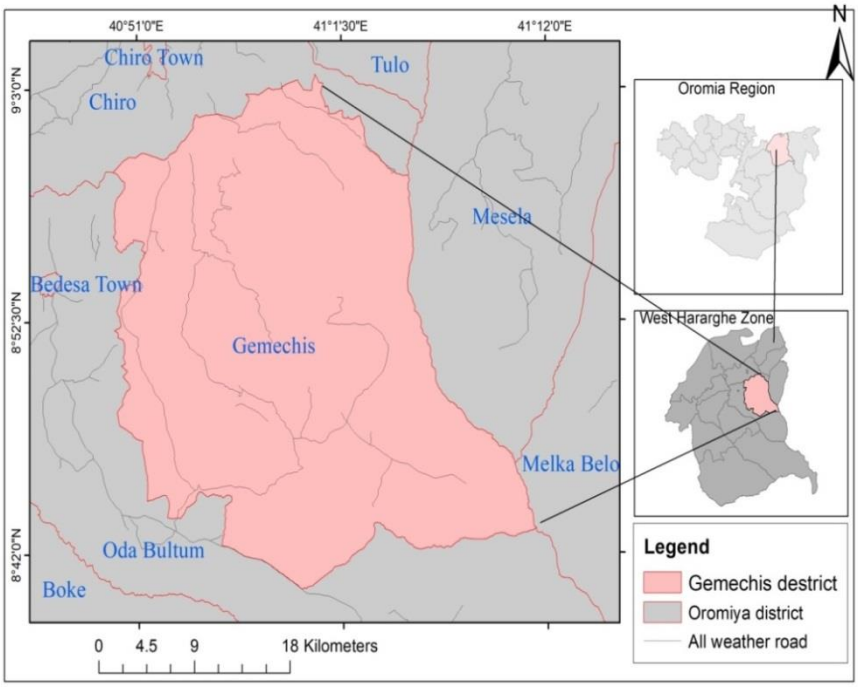

Figure 1. *Location map of Gemechis district.*

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, cited in [42].

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.

3.2. Method of Data Collection

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.

Sampling technique: Stratified sampling technique was followed based on altitudinal range.

3.3. Data Collections and Recordings

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.

3.4. Bee Forage Data Collection

3.4.1. 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.

3.4.2. 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, 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.

3.4.3. Bee Forages Diversity

1) Shannon index:

Shannon-Wiener index is the most commonly used diversity index and used to describe species diversity of different plant community types. It is calculated in the following way, $Shannon\ Index\ (H') = -\sum_{i=1}^{s} PilnPi$

Where s is the number of individual species, pi is the proportion of individuals or the abundance of the i^{th} species, and ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

2) Evenness

The evenness of the species within the plant community was calculated to indicate, how the cover of the plant species within a plot are distributed. Evenness values range from 0 to 1 [27]. An evenness value of 1 indicates that plant cover within a plot is evenly shared among the species present. The higher the values of the evenness index, the more even the species are in their distribution within the given area. Equitability (evenness) is calculated using the following formula:

$$J = \frac{H}{H'max}' = \frac{\sum_{i=1}^{S} PilnPi}{lns}$$

Where; H'= the value of the Shannon-Weiner diversity index, S= number of species in the community, Pi= the proportion of individuals of the i^{th} species expressed as proportion of total cover, ln= log $base_n$, J=Evenness of species in sampling area, H'max= Maximum value of diversity.

3) Comparing communities:

Comparing different sites using Jaccard's similarity index

An intuitive measure of similarity between two samples can summarize the fraction of species they share. Jaccard's index is the simplest summary of this, taking the following form:

$$J = \frac{S_a}{S_a+S_b+S_c}$$

Where,

a = the number of species common to both community types and

b =the number of species in one of the community to be compared

c = species present in the other site

3.5. Pollen Analysis of Honey

This study was conducted to analyze the pollen potentiality of Gemachis forest. Representative honey samples were collected from three sites; Chafe Kebena, Sororo and Arer Kebeles of Gemachis forest to determine the plant taxa found in honey. The extraction of pollen from honey was followed the methods recommended by the International Commission for Bee Botany. Accordingly, ten grams of honey were dissolved in 20 ml of distilled water and centrifuged (10 minutes, 7000 r/min). The resulting supernatant was discarded and the remaining residue was again diluted and centrifuged for 10 minutes at 7000 r/min. The final residue was transferred onto 75 x 25 mm microscope slides using a Pasteur pipette and left to dry. The sample area was covered with glycerin jelly and a cover slip. The pollen present in representative honey samples was observed with a microscope using 400 x magnifications. For quantification of the pollen types, at least 500 pollen grains were counted from each sample [7, 37]. The percentage frequency of the pollen taxa in all the samples was calculated excluding polleniferous plant species which were observed during honey pollen analysis. The types of pollen were allocated to one of four frequency classes for nectar source plants: predominant pollen types (>45% of the total pollen grains counted); secondary pollen types (16%-45%); important minor pollen types (3%-15%); and minor pollen types (3%) [29].

4. Results and Discussions

4.1. 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 1). 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 1. *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 reticulate*	√	√										
13	Giraaviliyaa	*Grevillea robusta*	√	√										
14	Goraa	*Rosa abyssinica*				√	√							
15	Hadaa	*Guizotia scabra*	√	√	√									
16	Handode	*Phytolacca dodecandra*	√	√										
17	Hanquu	*Embelia schimperi*								√				
18	Heexoo	*Hageniaia abyssinica*	√	√										

No	Local Name	Scientific Name	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
19	Koshommi	*Dovyalis caffra*								√	√			
20	Mixoo	*Rytigna neglecta*								√				
21	Qaxammee	*Maytenus sp.*							√	√				
22	Wadeessa	*Cordia africana*	√	√	√								√	√
23	Xaxessa	*Allophylus rubifolius*					√							

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 [20, 45] 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.

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 [45] 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 by [32, 43] 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 by [21, 32, 20] 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 [21, 43] 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 [11] 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).

4.2. 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 [2] 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, [35] also reported that Asteraceae, Leguminosae, Lamiaceae, Acanthaceae, Malvaceae, Poaceae, Euphorbiaceae, and Myrtaceae are the major bee forages families. These include shrub (54.1%), tree (16.6%) and herbs (29.1%) (Figure 2). The highest shrub population in the area is might be due to fast regeneration of woody plants or selective cutting of big trees. Furthermore, the Gemachis forest is one of the protected forest and less disturbed by the surrounding communities. This is in agreement with [42] who reported that the woody plant population is relatively higher than trees and herbs.

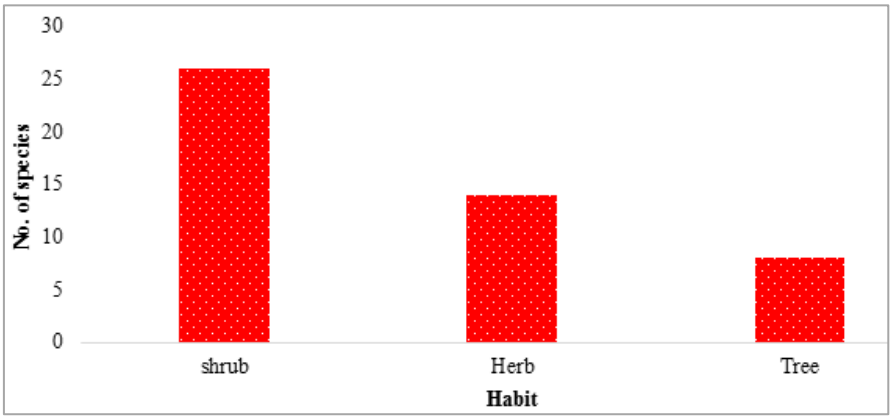

Figure 2. *Habit of the Plant.*

4.3. 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 Accordingly, *Solanium spp*, *Andropogon abyssinica*, *Guizotia spp* and *Hypoestes forskaolii* were the most abundant bee flora species in the study area (Figure 3). 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.

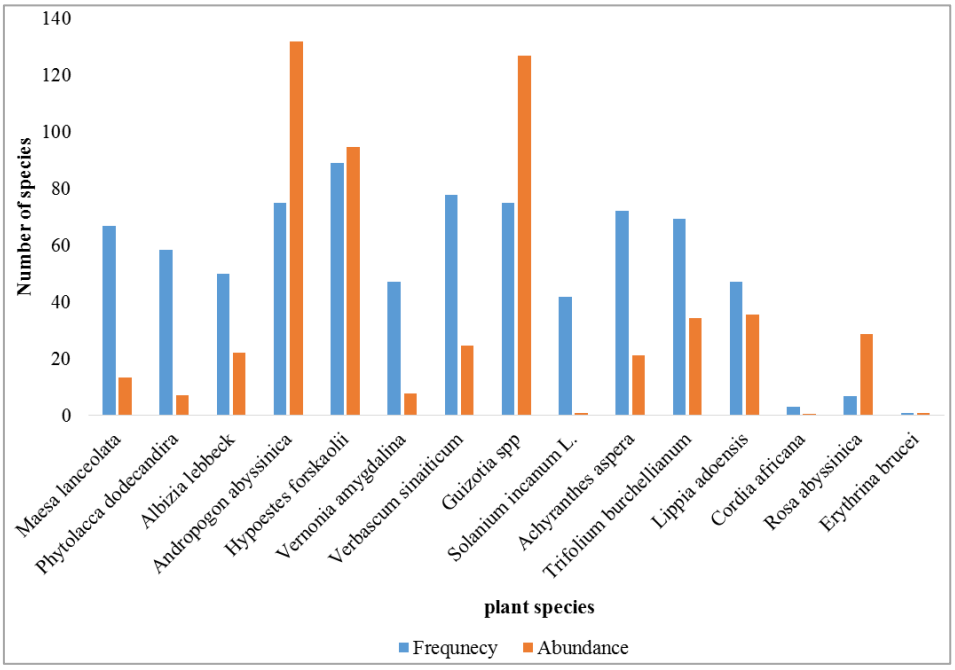

Figure 3. *Honeybee flora species abundance and frequency of Gemachis forest.*

4.4. 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 2). 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 2). 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.

Table 2. 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

4.5. 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 3). 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 3. 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		64.9%
Sororo and Arer	888		41.88%
Chafe Kebena, Sororo and Arer	13307		89.73%

4.6. 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 4, 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.

Table 4. 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*

Honey sample code	Agro ecology	Dominant pollen type	Minor pollen type
			(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*

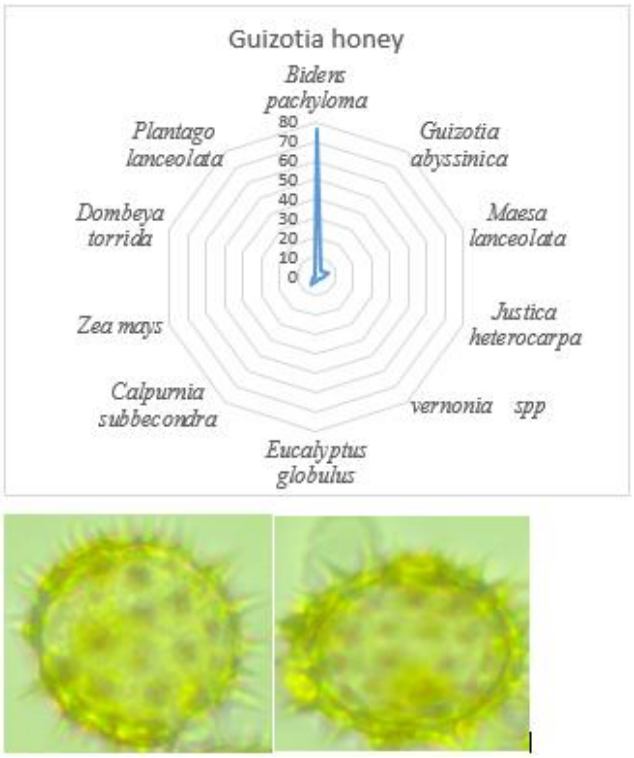

Figure 4. *Contributing Species for Guizotia spp honey from Arer site.*

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 4 and 5. *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.

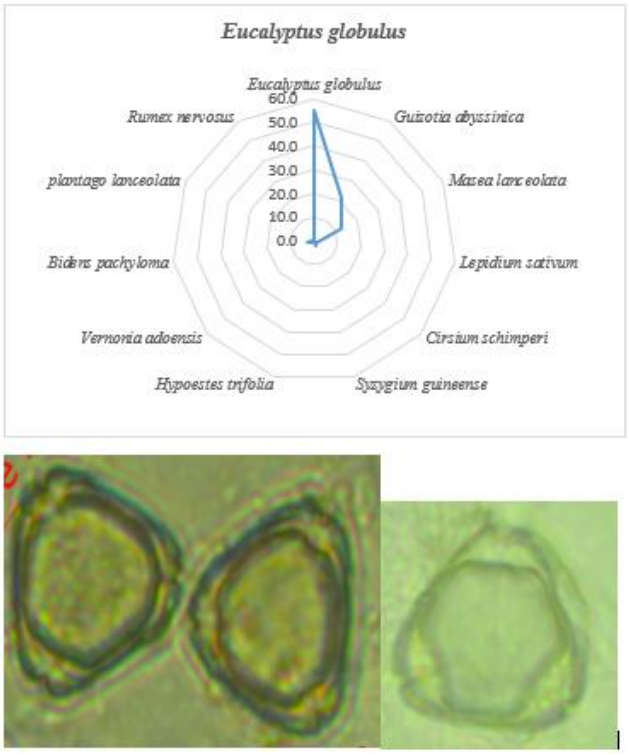

Figure 5. *Contributing Species for Eucalyptus globulus.*

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 [44] *Eucalyptus globulus* and *Guizotia scabra* are one of the potential monofloral honey source plants in Borena zone of Ormoia.

5. Conclusions and Recommendations

5.1. Conclusions

This study was conducted from October 2019 to November 2020 with the main objectives of Assessment of Bee Forage Diversity 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 species number of 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 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.

5.2. Recommendations

1) Beekeepers should utilize the forest for beekeeping activities, because the forest is of good plant diversity
2) Further research on establishment of flowering calendar and carrying capacity of the Gecmachis forest for beekeeping is highly recommended

Conflicts of Interest

The authors declare no conflicts of interests.

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