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Identification and characterization of honeybee flora calendar in Southwest Jimma Zone, Ethiopia

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Abstract. *Mossie T, Worku H. 2023. Identification and characterization of honeybee flora calendar in Southwest Jimma Zone, Ethiopia. Asian J For 7: 54-66.* The study was conducted to identify, characterize and document major bee forages, develop an appropriate flora calendar, their phenology, and pollen potential in the various agro-ecological conditions of the Jimma Zone, Ethiopia. A total of 90 beekeepers were purposefully selected from three districts and interviewed to get primary data. The density and abundance of flowering plants were determined using quadrat sampling techniques. In addition, pollen specimens were collected using pollen traps at seven-day intervals and were also traced back to plant species level under a light microscope. The study has revealed the presence of 141 pollen and/or nectar-source honeybee plant species belonging to sixty-two families in the study area. Herbs were the most dominant bee flora growth forms, accounting for 62 (44%) of a total of 141 honeybee plant species, followed by trees at 48 (34%) and shrubs at 31 (22%), respectively. The herbaceous plant had a greater density value of plant species per plot than did trees and shrubs. One hundred fifteen (81.6%) were both sources of pollen and nectar, whereas fifteen (10.6%) were pollen sources and the remaining eleven (7.8%) were nectar-source plant species. The Shannon diversity index and evenness were found to be 2.8 and 0.6, respectively. This indicated that the study area has a rich bee floral plant species and is suitable for beekeeping. Two main flowering periods of honeybee plants were followed by two honey flow seasons. Therefore, beekeepers should follow the floral calendar of honeybee plants to exploit the potential of the area for honey production.

Keywords: Bee flora species, flowering period, honeybees, trapped pollen

INTRODUCTION

Apiculture is a livestock industry that contributes significantly to a country's national and international economies, mainly in Africa. Ethiopia is still one of the top ten natural honey producers worldwide due to its diverse floral resources and favorable ecosystem conditions (Fichtl and Admassu 1994; Gidey and Mekonen 2010; Bareke and Addi 2020). It, directly and indirectly, contributes to household income and the national economy (Fenet and Alemayehu 2016). The production of honey, beeswax, pollen, royal jelly, and other by-products is the direct income source for the users, while contributing to plant pollination and the conservation of the natural environment, is the indirect role of honey bee production. Honeybees and plants have had a strong relationship for over 50 million years (FAO 1986). Beekeeping conserves natural resources and protects the global environment. It can be integrated with agricultural practices like crop production, horticulture crops, and the conservation of natural resources (Gezahegn 2001; Bareke and Addi 2020). Honey bees require feed for their production and reproduction, like other livestock species. It depends on flowering plants for their nutrition and protection. About 40, 000 plant species are used as honeybee forage across the world (Crane 1990). Among the flowering plants found in Ethiopia, 500 species are rich in nectar and pollen (Fichtl and Admasu 1994). Plants are classified as nectar or pollen-source plants based on the honeybee's activity of extending their proboscis and hind legs into flowers, respectively (Wubie et al. 2014; Jenberie et al. 2016; Pande and Gi 2018). Honeybees' main food sources are pollen and nectar. Nectar is a major component in the production of honey, whereas pollen is used as larval food, which is important in colony reproduction (Façade and Paul 2006).

Ethiopia has abundant natural and cultivated flora, as well as diverse agro-ecosystem and climatic conditions ideal for beekeeping. The presence of numerous honey plants is important for the country's honeybee colonies, production, and productivity. The botanical composition of natural vegetation differs depending on the agro-ecosystem , climate, and soil type (Gebretsadik 2016). The type and quantity of flora present determine the productivity and reproduction performance of honeybees (Amssalu 2007). Oromia is one of the Federal Republic of Ethiopia's regional states rich in natural resources and has favorable climatic conditions for improved beekeeping development. The region has virgin forests with high biodiversity, such as Harena, Yayu, Dindin, Anfarara, Munessa, Jibat, Chilimo, and Menagesha-Suba that are ideal for beekeeping. The region also contains cultivated crops such as oil and horticultural crops, as well as pulses, all of which can help to further the development of beekeeping. These make the region one of the potential areas for honeybee production.

Despite the region's diverse agro-ecosystem and climatic conditions, abundance of natural and cultivated flora, beekeepers lack a floral calendar for honeybee foraging and honey production. Flora calendar is a timetable that indicates the approximate duration of the flowering period, abundance, distribution, and honey potential of honeybee forages in various agro-ecosystem zones of the country (Amssalu 2004; Admasu et al. 2004). Identification and documentation of bee forage and their flowering calendar is critical for the sub-sectors development endeavors since the flowering periods of honeybee plants differ depending on the diversity of plant habits and environmental conditions (Tilahun 2003). Therefore, establishing a floral calendar is a critical tool for planning various beekeeping management operations, such as hive super adding, and predicting the frequency and period of honey flow in a given area. The length of the flowering period, nectar and pollen production, and honeybee plant availability in a specific area are all determined by agro-ecosystem and season. Therefore, assessing the different agro-ecosystem zones for determining the availability of bee forage, their life forms and establishing a flowering calendar of honey plants that enable effective seasonal colony management is paramount important. Furthermore, for optimal honey production, beekeepers should be aware of the flowering seasons of both main and minor nectar and pollen sources of plants in the vicinity of their apiary site (Francis 1990; Pearson and Braiden 1990). The study was conducted with the objective to characterize and document major bee forages, develop an appropriate flora calendar, and identify major mono- and multi-floral honey sources for effective bee management in various agro-ecosystem conditions of the Jimma Zone.

MATERIALS AND METHODS

Study area profile

The study was conducted in beekeeping potential areas of the Jimma Zone of the Oromia Regional State, Ethiopia, which geographically lies at a latitude of about 7013’-8 056’N and a longitude of about 35052’-37037’E (Figure 1). The area has high humidity and is rich in fauna and flora biodiversity. Three study districts (Goma, Gera, and Shebe Sombo) were selected based on ecosystem differences and beekeeping potential (Bareke and Addi 2019).

Honeybee flora inventory

The study was carried out in three beekeeping potential districts of Gera, Goma, and Shebe, representing highland, midland, and lowland agro-ecosystem. Agro-ecosystem representation was used to exploit bee flora species in different ecosystems of the study area. Three kebeles were selected from each district depending on their agro-ecosystem variation and potential for beekeeping activities. Household beekeepers were selected based on their experience in beekeeping and after discussion with district experts. A total of ninety (90) beekeepers, thirty (30) from each district, were also purposefully selected to get sound information on honey source plant lists, flowering periods, duration, beekeeping experience, number of colonies, number of harvests per year, and presence of poisonous plants. Well-structured questionnaires or checklists were created to collect both primary and secondary data from respondents, depending on their beekeeping experience in potential districts. A group discussion with experts, community groups, development agents, and farmer beekeepers was held to generate relevant information. Necessary and supportive data on plant nature and habitats, feeding resources, and plant phenology were collected following field observation. The types of honeybee forage, honey flow season, plants with adverse effects, swarming seasons, and management practices were considered during data collection.

Pollen sample collection and laboratory analysis

In total, 18 honey bee colonies were established in nine different locations across three districts of the study area in different agro-ecosystems.

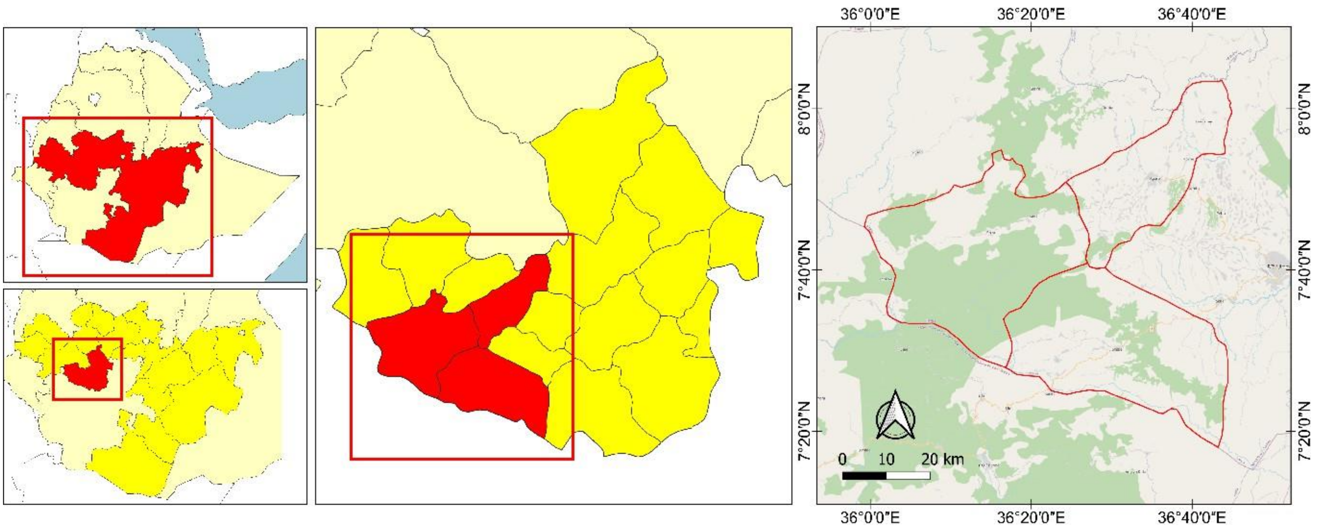

Figure 1. Study area map where samples were collected in the Jimma Zone, Oromia State, Ethiopia

At each site, two honeybee colonies were established for pollen trapping and pollen sample collection. Honeybee colonies were fitted with pollen traps and loads to collect and dislodge pollen pellet samples at seven-day intervals. In one year, a total of 66 pollen specimens were collected and used to determine the botanical origin of honeybee pollen. The fresh and dry weight of pollen pellets was recorded. The collected pollen was dried at room temperature overnight, and the fresh and dry pollen pellets were weighed and sorted by color. Each sorted pollen sample was identified at generic and species levels under the light microscope following diluting with ether solution. Using reference materials, plant species were identified from each type of pollen by comparing the shape, size, and apertures of the pollen. Pollen that we couldn't identify botanically using either analysis technique has been labeled as "unidentified."

Honeybee flora species composition and diversity

Assessment of plant species composition and diversity was performed in purposively selected districts based on beekeeping potential. For vegetation analysis using quadrat sampling techniques, two representative kebeles were chosen from each district based on vegetation coverage and ecosystem difference (highland, midland, and lowland). The diversity and composition of honeybee plants were determined according to Tesfaye et al. (2013) plant density determination method. The quadrat/plot size varied depending on vegetation types. Honeybee plants were classified as trees, shrubs, and herbaceous. Tree and shrub sampling plots were 20 m × 20 m in size, whereas herbaceous plant sampling plots were 2 m x 2 m in a two-kilometer radius every 0.1 km from the hive to estimate the frequency and density of bee plants. The main plots were laid out systematically considering the availability of vegetation coverage, and then small quadrats of 2 m x 2 m plots were laid out at different sites of the main plots to understand the forgeable area of honey plants. A total of 60 plots were taken for the districts, representing different agro-ecosystems. Then, plant species within quadrats were counted for the assessment of plant density and frequency in specific sampling sites. Honeybee flora species abundance was defined and computed in all quadrats, and density was calculated in hectares. Plant specimens were collected during flowering seasons with necessary botanical features like leaves, flowers, and a portion of the stem. The collected specimens were pressed, identified, and then compared to the published report at the Holeta Bee Research Center.

Richness and diversity of bee forage plants

The Shannon-Wiener diversity index, species richness, and Shannon's evenness were used to determine the diversity of bee forage plant species. The Shannon-Wiener diversity index is the most widely used non-sample-size-dependent measure of species diversity (Ramirez-Arriaga et al. 2011).

Shannon index (H') =∑ (pi*lnpi), where H' = Shannon index, pi= proportion of individual species, and Ln= log base n.

Evenness (J) = H'/ H'max = H'/INS, where H' =Shannon diversity index, H'max = lns where S is the number of species, Ln = logbase. The value of evenness is found between zero to one (Kent and Coker 1992).

Statistical analysis

Data on bee flora species, abundance, frequency, diversity, and pollen count were summarized using descriptive statistics. The data were thoroughly examined using Microsoft Excel and the Statistical Package for Social Sciences (SPSS). And the results were presented in a table format.

RESULTS AND DISCUSSION

Survey result

A total of 39 pollen and/or nectar source plant species belonging to 23 families were identified during the survey work (Table 1). Bee floral plant species were classified as herbs, shrubs, and trees and wild and cultivated based on growth forms and source of bee plants. According to the survey results, trees (62.5%) were the most important source of bee forages, followed by herbs (25%) and shrubs (12.5%). The foremost sources of honeybee forages were wild 116 (82.3%) and cultivated 25 (17.7%). Honeybee plant species indicated by beekeepers during the survey were categorized as very good, good, and poor based on their abundance in the study area And most of the bee floral species identified through the survey were categorized as high in their abundance.

Coffea arabica, *Croton macrostachyus*, *Vernonia* spp., *Guizotia scabra*, *Eucalyptus camaldulensis*, *Cordia africana*, *Mangifera indica*, and *Combretum molle* were the most common honeybee plant species identified by beekeepers in different agro-ecosystems (Table 1). The dominant honeybee plant species in the highland were *Vernonia* spp., *Schefflera abyssinica*, *C. macrostachyus*, *C. arabica*, and *Bidens* spp., while the most frequently visited bee floral species in lowland ecology were *C. africana*, *G. scabra*, *C. molle*, *E. camaldulensis*, *Bidens* spp., and *C. arabica*. On the other hand, *G. scabra*, *Vernonia* spp., *C. arabica*, *C. macrostachyus*, and *Bidens* spp., were the most abundant floral plant species in midland agro-ecology based on survey results. *Vernonia* spp., *C. africana*, and *G. scabra* were the most abundant plant species in the highland, midland, and lowland, respectively. Frequently indicated bee floral species by beekeepers were *Vernonia* spp, *C. arabica*, *C. macrostachyus*, and *G. scabra* with 90 (100%), 83 (92.2%), 77 (85.6%) and 73(81%) rate, respectively. The most widely distributed bee flora species in all agro-ecosystem were *Vernonia* spp.. *S. abyssinica* and *C. molle*, two bee flora species, were only found in highland and lowland agro-ecosystem, respectively.

Honey yields were harvested twice a year by 68.9% of beekeepers and three times by 17.8% of beekeepers in different agro-ecologies of the study area. The average honey yields for highland, lowland, and midland were 25.3, 23.3, and 30.2 kg from frame hives, respectively. The major honey flow seasons in the study area across different agro-ecosystem are October to December, February to April, and May to June (Figure 2). The flowering period and duration of flowering time of honeybee plants differ significantly across the study area's agro-ecosystems ($p< 0.05$). The major flowering months of the study area are September, October, February, March, April, May and June (Table 1). On the other hand, according to beekeepers who participated in the survey, the study area's dearth periods were August, July, and January. The maximum and minimum flowering duration of bee plant species were ninety and seven days, respectively. *C. macrostachyus*, *Vernonia* spp., *E. camaldulensis*, *G. scabra*, and *Trifolium* spp. had the longest flowering periods and offered a steady supply of nectar and pollen to honeybees on the hunt.

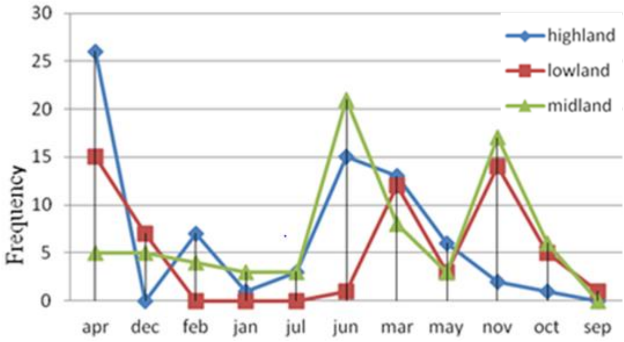

Figure 2. Honey flow month in different agro-ecosystems

Table 1. Major honeybee plants identified by beekeepers

Local name	Scientific name	Family name	Species abundance	Life forms	Food source	Flowering month	Duration (days)
Buna	*Coffea arabica*	Rubiaceae	2	Shrub	Pol/Nec	Feb, Mar	60
Bisana	*Croton macrostachyus*	Euphorbiaceae	2	Tree	Pol/nec	Jun, May, Aug, Apr	90
Girawa	*Vernonia* spp.	Asteraceae	1	Tree	Nectar	Dec-Mar	90
Tufo	*Guizotia scabra*	Asteraceae	2	herb	Pol/nec	Aug-Dec	90
Bahrzaf	*Eucalyptus camaldulensis*	Myrtaceae	3	Tree	Pol/nec	Year round	90
Wanza	*Cordia africana*	Boraginaceae	2	Tree	Poll/nec	Aug, Jul, Sep	60
Abalo	*Brucea antidysenterica*	Simaroubaceae	3	Tree	Pol/Nec	Apr,Mar	15
Avocado	*Persea americana*	Lauraceae	2	Tree	Pollen	Sep, Oct, Jan, Feb, Apr	90
Mango	*Mangifera indica*	Anacardiaceae	3	Tree	Pol/Nec	Mar, Dec, Feb	60
Tensa	*Combretum molle*	Combretaceae	1	Tree	Nectar	Mar, Apr, Feb	60
Boqolo	*Zea mays*	Poaceae	2	herb	Pollen	Jul, Jun, May	60
Adeye ababa	*Bidens* spp.	Asteraceae	1	herb	Pollen	Sep, Oct, Nov, Dec	60
Girar	*Acacia* spp.	Fabaceae	2	Tree	Pollen/nectar	Apr, May, Dec, Jan, Feb	60
Geteme	*Schefflera abyssinica*	Araliaceae	1	Tree	Pollen/nectar	Apr, Mar, May	60
Kerero	*Aningeria altissima*	Sapotaceae	2	Tree	Nectar	Apr, Jun, May, Jul	60
Turba abeba	*Brugmansia suaveolens*	Solanaceae	3	Shrub	Pollen/nectar	Almost year round	60
Siddessa	*Trifolium* spp.	Fabaceae	3	Herb	Pollen/nectar	Sep, Oct, Jan, Feb, Mar	90
Rejii	*Vernonia rueppellii*	Asteraceae	2	Shrub	Pollen/ nectar	Dec, Jan, Feb, Mar	60
Sesbania	*Esbania sesban*	Fabaceae	2	Shrub	Pollen	Year round	15
Sesa	*Albizia gummifera*	Fabaceae	2	Tree	Pollen /nectar	Feb, Mar	30
Wandabiyo	*Apodytes dimidiate*	Icacinaceae	2	Tree	Pollen/nectar	Feb, Oct, Mar	30
Bayya	*Olea welwitschi*	Oleaceae	2	Tree	Pollen/nectar	Dec,Feb, Jan	60
Keryo	*Polyscias fulva*	Araliaceae	2	Tree	Pollen/nectar	Apr, Mar, May, Jun	30
Mashila	*Sorghum bicolor*	Poaceae	2	Herb	Pollen	Sep, Oct, Mar	30
Kenchib	*Euphorbia tirucalli*	Euphorbiaceae	3	Herb	Nectar	Sep, Oct, Mar	60
Nuge	*Guizotia abyssinica*	Asteraceae	3	Herb	Pollen/Nectar	Sep, Oct	30
Sio	*Rhus* spp.	Anacardiaceae	2	Tree	Pollen/nectar	Aug, Jul, Sep, Oct	60
Sombo	*Ekebergia capensis (E. rueppeliana*	Maliaceae	3	Tree	Pollen /nectar	Dec, Jan, Mar, Oct, Nov	30
Zytune	*Psidium guajava*	Myrtaceae	3	Tree	Pollen/nectar	Jan	7
Giravilla	*Grevillea robusta*	Proteaceae	2	Tree	Pollen /nectar	Mar	20
Ruze	*Oryza sativa*	Poaceae	3	Herb	Pollen	Sep, Oct	30
Sesame	*Sesamum indicum*	Pedaliaceae	2	Herb	Pollen /nectar	Mar,May, Jun,Ssep	60
Sole	*Olinia rochetiana*	Penaeaceae	2	Tree	Pollen/nectar	Sep, Mar	60
Bedesa	*Syzygium guineense*	Myrtaceae	2	Tree	Pollen /Nectar	Jan, Feb, Mar, Sep, Aug	
Maget	*Trifolium* spp.	Papilionaceae	2	Tree	Nectar	Mar	
Korch	*Erythrina abyssinica*	Fabaceae	3	Shrub	Pollen /nectar	Jan, Mar	30
Zembaba	*Phoenix reclinata*	Arecaceae	3	Tree	Pollen	Mar	15
Derbata	*Terminalia laxiflora*	Combretaceae	3	Tree	Nectar	Sep, Mar	30
Seho	*Allophylus abyssinicus*	Sapindaceae	3	Tree	Pollen/nectar	Aug	60

Poisonous honeybee plant species were also identified in the study areas, along with their flowering times and durations. About 65 (77.2%) of respondents were aware of the presence of poisonous plants for honeybees. The remaining 25 (27.8%) had no awareness of the availability of poisonous honeybee plants in their surrounding areas. Honeybee poisonous plants found in the study area were key abeba, tikur enchet, and nime tree. *Euphorbia cotinifolia* is a shrub that belongs to the family Euphorbiaceae, which is the most frequently, identified poisonous plant species. *E. cotinifolia* plant species mainly found in highland and midland agro-ecosystems. The major flowering months of *E. cotinifolia* species are September to November, February to April, and May to June in the study areas. The maximum and minimum flowering durations of plants were 90 days and 7 days, respectively.

Bee pollen analysis

Twenty-four honey bee plant species belonging to ten families were identified from a total of sixty-six (66) pollen samples collected in different districts (Table 2). *Guizotia abyssinica, Vernonia* spp., *C. arabica*, and *Eucalyptus* spp. were the major pollen-source honeybee plant species identified in the study areas (Figure 3). On the other hand, *Bersama abyssinica, Olea africana, Syzygium guineense* and *Syzyjium* spp. were the minor pollen sources of honey bee plant species, as the present findings indicated. The current study found that the highest proportion of pollen grains was collected in October (46.3%), November (14.6%), February (12.2%), and December (11.0%). The lowest pollen grains were collected in July and August.

Honeybee flora species abundance and density

Ninety eight honeybee plant species belonging to 47 families were identified from 60 main plots and subplots (Table 3). These honeybee plant species were classified as herbs, shrubs, and trees depending on growth forms of plants. Herbs were the most frequently visited plant growth form, accounting for 49 (50%) of all visits, followed by trees at 26 (26.5%) and shrubs at 23 (23.5%) in sample plots. The Fabaceae (31.9%), Asteraceae (19.1%) and Poaceae (14.8%) families had the most honey bee plant species encountered in quadrat samples.

The most common or top ten floral honeybee plant species in highland sample plots/quadrats were *Cynoglossum lanceolatum*, *C. arabica*, *Isoglosa* species, *Snowdenia polystachya*, *Pennisetum glaucum*, *Desmodium* species, *Tinospora cordifolia*, *Acanthus eminens*, *E. camaldulensis* and *Cyclamen purpurascens* (Table 4). The *C. lanceolatum*, *S. polystachya*, *Bidens* spp., *Sorghum bicolor*, *Isoglosa* spp., *Kalanchoe pinnata*, *Erythrina abyssinica*, *Euphorbia tirucalli*, *Vernonia auriculifera* and *Lippia adoensis* were the most frequent honeybee plant species in lowland plots, whereas *C. lanceolatum*, *E. camaldulensis*, *Colocasia esculenta*, *S. polystachya*, *K. pinnata*, *Erica* spp., *Psidium guajava*, *Arum maculatum* and *G. scabra* were the dominant honeybee plant species in midland sample plots (Table 4).

Diversity and composition of honeybee forages

A total of one hundred forty-one pollen and/or nectar-source bee plant species belonging to sixty-two families were discovered based on the survey, pollen load collection, and plant inventory data results. Herbs were the most dominant bee flora, accounting for 62 (44%) of a total of 141 honeybee plant species, followed by trees at 48 (34%) and shrubs at 31 (22%), respectively (Figure 4). The families with the highest number of species were Fabaceae 18(12.8%), Asteraceae 11 (7.8%), Poaceae 9 (6.4%), Solanaceae 6 (4.3%), Acanthaceae 4 (2.8%) and Euphorbaceae 4 (2.8%) in the study area (Figure 5). Among a total of one hundred forty-one honeybee plant species, one hundred fifteen (81.6%) were both sources of pollen and nectar, whereas fifteen (10.6%) were pollen sources and the remaining eleven (7.8%) were nectar source plant species.

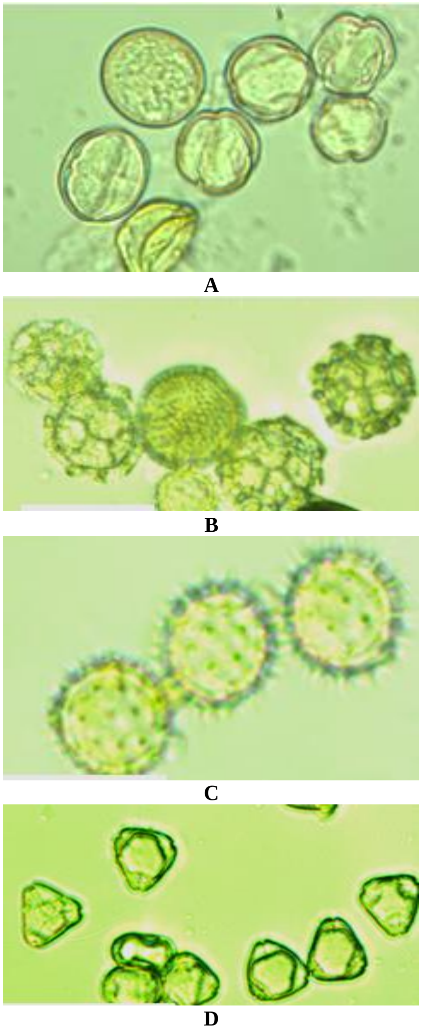

Figure 3. Major honeybee flora species identified through pollen analysis. A. *Coffea arabica*, B. *Vernonia* spp., C. *Guizotia* spp., D. *Eucalyptus* spp.

Table 2. Bee plant species identified from pollen analysis and harvesting period

Scientific/species name	Family name	Life forms	Source of food	Harvesting period
Guizotia abyssinica	Asteraceae	Herb	Pollen/nectar	Sep-Feb
Vernonia amygdalina	Asteraceae	Tree	Pollen/nectar	Jan-Feb, Apr
Coffea arabica	Rubiaceae	Shrub	Pollen/nectar	Jan-Apr, Oct-Nov
Eucalyptus spp.	Myrtaceae	Tree	Pollen/nectar	De-Jan, Oct-Nov
Bidens spp.	Asteraceae	Herb	Pollen/nectar	Oct-Jan
Trifoluma spp.	Fabaceae	Herb	Pollen/nectar	Oct, Dec-Jan
Parkinsonia aculeata	Fabaceae	Tree	Pollen/nectar	Oct, Nov
Rubus spp.	Rosaceae	Herb	Pollen/nectar	Oct, Dec-Jan
Schefflera abyssinica	Araliaceae	Herb	Pollen/nectar	Oct, Jan
Grass spp.	not id	Herb	Pollen/nectar	Oct
Plantago lanceolata	Plantaginaceae	Herb	Pollen	Mar
Olea africana	Oleaceae	Tree	Pollen/nectar	Feb
Bersama abyssinica	Francoaceae	Tree	Pollen/nectar	Oct
Brassica spp.	Brassicaceae	Herb	Pollen/nectar	Oct
Caesalpinia sp.	Fabaceae	Herb	Pollen/nectar	Dec
Caesalpinia decapitala	Fabaceae	Shrub	Nectar	Dec
Combretum molle	Combretaceae	Tree	Nectar	Oct
Datura arborea	Solanaceae	Shrub	Pollen	Dec
Syzygium guineense (Willd.) DC	Myrtaceae	Tree	Pollen/nectar	Oct
Echoriopis spp.	Cactaceae	-	Pollen	Dec
Ejursaw spp.	not id	-	Pollen	Feb
Rubuytmaeso lanceolata	not id	-	Pollen	Mar
Syzygium spp.	Myrtacea	Tree	Pollen	Oct

Table 3. Honeybee plant species density and frequency in sample quadrats

Local name	Scientific name	Family	Plant type	Plant count	Plant density/ha	Plot obs.
Ambebesa/sesa	*Albizia gummifera*	Fabaceae	Tree	44	267	9
Arenchi	*Pavonia urens*	Malvaceae	Herb	89	8663	8
Bahrzaf	*Eucalyptus camaldulensis*	Myrtaceae	Tree	704	4689	8
Banana	*Musa acuminata*	Musaceae	Tree	82	2050	3
Bisana	*Croton macrostachyus*	Euphorbiaceae	Tree	34	174	12
Buna	*Coffea arabica*	Rubiaceae	Shrub	1739	4329	30
Castor/gulo	*Ricinus communis*	Euphorbiaceae	Shrub	47	279	10
Demekese	*Ocimum lamiifolium* Hochst	Labiatae	Herb	16	4782	4
Dergu	*Isoglosa* species	Acanthaceae	Herb	464	69074	50
Emo	*Colocasia esculenta*	Araceae	Herb	352	1996	10
Girawa	*Vernonia* spp.	Asteraceae	Tree	77	261	22
Girnche/chifrig	*Sida schimperiana*	Malvaceae	Herb	222	2500	19
Kello/adey abeba	*Bidens* spp.	Asteraceae	Herb	497	37499	30
Metene	*Cynoglossum lanceolatum*	Boraginaceae	Herb	2514	68281	110
Muja	*Snowdenia polystachya*	Poaceae	Herb	944	141250	31
Rejii	*Vernonia auriculifera*	Asteraceae	Shrub	133	762	13
Susbania	*Esbania sesban*	Fabaceae	Shrub	72	679	9
Tufo	*Guizotia scabra*	Asteraceae	Herb	60	67944	25
Ulmaye/limich	*Clausena anisata*	Rutaceae	Shrub	22	244	7
Abayi/qalawa	*Maesa lanceolata*	Myrsinaceae	Tree	14	200	4
Arebe duberti	*Carduus schimperi*	Asteraceae	Herb	58	42916	7
Birbira	*Millettia ferruginea*	Fabaceae	Tree	7	113	3
Bosoke	*Kalanchoe* sp.	Crassulaceae	Herb	95	52000	9
Chat	*Kalanchoe pinnata*	Crassulaceae	Shrub	320	4001	4
Cheda dima	*Euphorbia tirucalli*	Euphorbiaceae	Shrub	142	1354	5
Desmodium	*Desmodium* species	Fabaceae	Herb	209	29583	20
Endod	*Phytolacca dodecandra*	Phytolaccaceae	Herb	29	46250	5
Gomenzer	*Brassica carinata*	Brassicaceae	Herb	15	37500	2
Haallaal	*Urera hypselodenron*	Urticaceae	Shrub	44	83750	4
Kontir	*Caesalpinia decapetala*	Fabaceae	Shrub	65	1116	4
Korch	*Erythrina abyssinica*	Fabaceae	Tree	143	1131	6
Mango	*Mangifera indica*	Anacardiaceae	Tree	2	50	2
Qortobi	*Plantago lanceolata*	Plantaginaceae	Herb	42	31875	6
Sanaa maki	*Senna didymobotrya*	Fabaceae	Shrub	8	200	2

Sindedo	*Pennisetum thunbergii*	Poaceae	Herb	18	45000	2
Sokoro	*Acanthus eminens*	Acanthaceae	Herb	97	681	5
Ulaga	*Ehretia cymosa*	Boraginaceae	Tree	5	58	4
Wanza	*Cordia africana*	Boraginaceae	Tree	17	148	9
Zeytuna	*Psidium guajava*	Myrtaceae	Tree	145	925	7
Adenguare	*Phaseolus vulgaris*	Fabaceae	Herb	3	7500	1
Agam	*Carissa spinarum*	Apocynaceae	Shrub	4	100	1
Alenge	*Arum maculatum*	Araliaceae	Herb	121	302500	1
Allala	*Allamanda* spp.	Apocynaceae.	Herb	13	16250	2
Ananno	*Periploca linearifolia*	Asclepiadaceae	Shrub	30	375	2
Apple	*Malus pumila*	Rosaceae	Shrub	2	50	1
Asangira	*Datura stramonium*	Solanaceae	Herb	9	11250	2
Askira	*Millettia ferruginea*	Fabaceae	Tree	15	63	6
Avocado	*Persea americana*	Lauraceae	Tree	5	25	5
Baddessa/Dokima	*Syzygium guineense*	Myrtaceae	Tree	2	50	1
Besobila /kefo	*Salvia nilotica/Ocimum basilicum*	Lamiaceae	Herb	6	15000	1
Boqqo	*Bersama abyssinica*	Melianthaceae	Tree	1	25	1
Bosoka	*Eriobotrya japonica*	Rosaceae	Tree	1	25	1
Butte	*Ammocharis tinneana*	Amaryllidaceae	Herb	8	10000	2
Cassava	*Manihot esculenta*	Euphorbiaceae	Shrub	124	1550	2
Cheka	*Calpurnia aurea*	Fabaceae	Tree	4	100	1
Chibo	*Vernonia leopoldi*	Asteraceae	Shrub	18	450	1
Damisa	*Centella asiatica*	Apiaceae	Herb	7	17500	1
Dhumuga	*Justica schimperiana*	Acanthaceae	Shrub	16	400	1
Diniche	*Solanum tuberosum*	Solanaceae	Herb	20	16666	3
Dobbi/sama	*Urtica simensis*	Urticaceae	Herb	34	42 500	2
Enselal	*Foeniculum vulgare*	Apiaceae	Herb	2	5000	1
Enset	*Ensete ventricosum*	Musaceae	Shrub	33	413	2
Girar	*Acacia* spp.	Fabaceae	Tree	3	75	1
Gomera	*Capparis tomentosa*	Capparidaceae	Shrub	1	25	1
Guriyo	*Tinospora cordifolia*	Menispermaceae	Herb	141	88125	4
Harbu/shola	*Ficus sur*	Moraceae	Tree	2	50	1
Hidda bofa	*Momordica foetida*	Cucurbitaceae	Herb	1	25	1
Hiddaa lafaa	*Dregea schimperi*	Asclepiadaceae	Herb	8	6666	3
Hiddi	*Solanum incanum*	Solanaceae	Shrub	5	4166	3
Jajjab	*Setaria megaphylla*	Poaceae	Herb	26	32500	2
Karaba	*Sida rhombifolia*	Malvaceae	Herb	26	7222	9
Kase	*Lippia adoensis*	Verbenacae	Herb	86	107,500	2
Kishkishe	*Senna septemtrionalis*	Fabaceae	Herb	7	17500	1
Kunche	*Chenopodium album*	Amaranthaceae	Herb	21	17500	1
Kusaye	*Lantana trifolia*	Verbenaceae	Shrub	2	50	1
Lochisa	*Bersama abyssinica*	Melianthaceae	Herb	35	875	1
Mixoo/dido/didu	*Galiniera saxifrage*	Rubiaceae	Shrub	2	50	1
Mulberry	*Morus alba*	Moraceae	Shrub	3	75	1
Nanaye	*Pennisetum glaucum*	Poaceae	Herb	196	61 250	8
Pepper /berberi	*Capsicum annuum*	Solanaceae	Herb	18	4500	1
Qalawa/qaawaa	*Grewia mollis*	Tiliaceae	Tree	1	25	1
Qumudu	*Nymphoides indica*	Menyanthaceae	Herb	41	34166	2
Raafu	*Kleinia grantii*	Asteraceae	Herb	17	21250	3
ret/alovera	*Aloe debrana*	Xanthorrhoeaceae	Herb	17	42500	1
Rhodus	*Chloris gayana*	Poaceae	Herb	1	2500	1
Shajara	*Cyclamen purpurascens*	Primulaceae	Herb	80	33333	6
Shenkora	*Saccharum officinarum*	Poaceae	Shrub	6	150	1
Shultee	*Rumex nepalensis*	Polygonaceae	Herb	6	15000	1
Siddisa/wazma	*Trifolium rueppellianum*	Fabaceae	Herb	39	97500	1
Siglu	*Fagaropsis angolensis*	Rutaceae	Tree	6	150	1
Sorghum	*Sorghum bicolor*	Poaceae	Herb	135	1688	2
Suufi/suff	*Carthamus tinctorius*	Asteraceae	Herb	56	46666	3
Togo	*Dieliptera* spp.	Acanthaceae	Tree	10	25000	1
Tsid	*Juniperus procera*	Cupressaceae	Tree	40	1000	1
Uregessa	*Clausena anisata*	Rutaceae	Tree	11	138	2
Vetch	*Vicia sativa*	Fabaceae	Herb	6	15000	1
Welensu	*Erythrina brucei*	Fabaceae	Tree	41	513	2
Yeriwo garo	*Solanecio* spp.	Asteraceae	Herb	1	25	1

Table 4. Honeybee plant species density and their frequency of occurence in ecosystems

Scientific name	Family name	Highland			Lowland			Midland			
		Plant count	Plant den./ha	Plot obs.	Plant count	Plant den./ha	Plot obs.	Plant count	Plant dens./ha	Plot obs.	Type of plants
Vernonia spp.	Asteraceae	48	100	12	10	42	6	19	119	4	Tree
Coffea arabica	Rubiaceae	425	1181	9	604	1373	11	710	1775	10	Tree
Croton macrostachyus	Euphorbiaceae	20	84	6	1	25	1	13	65	5	Tree
Vernonia rueppellii	Asteraceae	27	135	5	92		5	14	167	3	Shrub
Albizia gummifera	Fabaceae	8	67	3	1	25	1	35	175	5	Tree
Eucalyptus camaldulensis	Myrtaceae	112	933	3	3	75	1	589	3681	4	Tree
Malus pumila	Rosaceae	2	50	1	-	-	-	-	-	-	Shrub
Acacia spp.	Fabaceae	3	75	1	-	-	-	-	-	-	Tree
Acanthus eminens	Acanthaceae	93	581	4	-	-	-	4	100	1	Herb
Allamanda spp.	Apocynaceae.	-	-	-	13	16250	2	-	-	-	Herb
Aloe debrana	Xanthorrhoeaceae	-	-	-	-	-	-	17	42500	1	Herb
Ammocharis tinneana	Amaryllidaceae	8	10000	2	-	-	-	-	-	-	Herb
Arum maculatum	Araliaceae	-	-	-	-	-	-	121	30250	1	Herb
Bersama abyssinica	Melianthaceae		36	900	2	-	-	35	875	1	Tree
Bidens spp.	Asteraceae	32	13333	6	407	56 527	18	58	24166	6	Herb
Brassica carinata	Brassicaceae	11	27500	1	-	-	-	4	10000	1	Herb
Caesalpinia decapetala	Fabaceae	23	192	3	-	-	-	42	924	1	Shrub
Calpurnia aurea	Fabaceae	-	-	-	-	-	-	4	100	1	Tree
Capparis tomentosa	Capparidaceae	-	-	-	1	25	1	-	-	-	Shrub
Capsicum annuum	Solanaceae	-	-	-	-	-	-	18	4500	1	Herb
Carduus schimperi	Asteraceae	26	16250	4	-	-	-	32	26666	3	Herb
Carissa spinarum	Apocynaceae	-	-	-	-	-	-	4	100	1	Shrub
Carthamus tinctorius	Asteraceae	-	-	-	56	46666	3	-	-	-	Herb
Centella asiatica	Apiaceae	7	17500	1	-	-	-	-	-	-	Herb
Chenopodium album	Amaranthaceae	21	17500	3	-	-	-	-	-	-	Herb
Chloris gayana	Poaceae	1	2500	1	-	-	-	-	-	-	Herb
Clausena anisata	Rutaceae	2	50	1	9	56	4	22	276	4	Shrub
Colocasia esculenta	Araceae	-	-	-	54	675	2	286	1021	7	Herb
Cordia africana	Boraginaceae	-	-	-	8	67	3	5	31	4	Tree
Cyclamen purpurascens	Primulaceae	80	33333	6	-	-	-	-	-	-	Herb
Cynoglossum lanceolatum	Boraginaceae	997	51, 927	48	643	53 583	30	874	68281	32	Herb
Datura stramonium	Solanaceae	-	-	-	9	11250	2	-	-	-	Herb
Desmodium species	Fabaceae	142	29583	12	-	-	-	104	21862	9	Herb
Dieliptera spp.	Acanthaceae	-	-	-	10	25000	1	-	-	-	Tree
Dracaena afromontana	Dracaenaceae	12	300	1	-	-	-	-	-	-	Tree
Dregea schimperi	Asclepiadaceae	8	6666	3	-	-	-	-	-	-	Herb
Ensete ventricosum	Musaceae	-	-	-	-	-	-	33	413	2	Shrub
Ehretia cymosa	Boraginaceae	4	33	3	1	25	1	-	-	-	Tree

Eluesine folicofolia	Poaceae	4	10000	1							Herb
Erica spp.	Ericaceae	1	2500	1	-	-	-	166	69166	6	Herb
Eriobotrya japonica	Rosaceae	-	-	-	1	25	1	-	-	-	Tree
Erythrina abyssinica	Fabaceae	38	475	2	105	656	4	-	-	-	Tree
Erythrina brucei	Fabaceae	-	-	-	-	-	-	41	513	2	Tree
Sesbania sesban	Fabaceae	28	116	6	1	25	1	43	538	2	Shrub
Euphorbia tirucalli	Euphorbiaceae	41	512	2	101	842	3	-	-	-	Shrub
Manihot esculenta	Euphorbiaceae	-	-	-	-	-	-	124	1550	2	Shrub
Fagaropsis angolensis	Rutaceae	-	-	-	-	-		6	150	1	Tree
Ficus sur	Moraceae	2	50	1	-	-	-	-	-	-	Tree
Foeniculum vulgare /*Anethum graveolens*	Apiaceae	-	-	-	-	-	-	2	5000	1	Herb
Galiniera saxifrage	Rubiaceae	2	50	1	-	-	-	-	-	-	Shrub
Grewia mollis	Tiliaceae	1	25	1	-	-	-	-	-	-	Tree
Guizotia scabra	Asteraceae	4	10000	1	56	28000	5	10 2	29944	19	Herb
Isoglosa species	Acanthaceae	266	24629	27	120	30000	10	78	15000	13	Herb
Juniperus procera	Cupressaceae	-	-	-	-	-	-	40	1000	1	Tree
Justica schimperiana	Acanthaceae	-	-	-	-	-	-	16	400	1	Shrub
Kalanchoe pinnata	Crassulaceae	-	-	-	109	1363	2	211	2638	2	Shrub
Kalanchoe sp.	Crassulaceae	54	27000	5	41	25000	4	-	-	-	Herb
Kleinia grantii	Asteraceae	-	-	-	-	-	-	17	21250	2	Herb
Lantana trifolia	Verbenaceae	-	-	-	-	-	-	2	50	1	Shrub
Lippia adoensis	Verbenacae	-	-	-	86	107500	2	-	-	-	Herb
Maesa lanceolata	Myrsinaceae	9	75	3	-	-	-	5	125	1	Tree
Mangifera indica	Anacardiaceae	-	-	-	1	25	1	1	25	1	Tree
Millettia ferruginea	Fabaceae	5	63	2	15	63	6	2	50	1	Tree
Momordica foetida	Cucurbitaceae	-	-	-	1	25	1	-	-	-	Tree
Morus alba	Moraceae	-	-	-	-	-	-	3	75	1	Shrub
Musa acuminata	Musaceae	32	800	1	13	325	1	-	-	-	Tree
Nymphoides indica	Menyanthaceae	-	-	-	-	-	-	41	34166	3	Herb
Ocimum lamiifolium	Labiatae	-	-	-	12	11325	3	4	100	1	Herb
Pavonia urens	Malvaceae	41	5625	4	1	2500	1	47	538	3	Herb
Pennisetum glaucum	Poaceae	196	61 250	8	-	-	-	-	-	-	Herb
Pennisetum thunbergii	Poaceae	-	-	-	-	-	-	14	35000	1	Herb
Periploca linearifolia	Asclepiadaceae	-	-	-	-	-	-	30	37875	2	Shrub
Persea americana	Lauraceae	-	-	-	-	-	-	5	25	5	Tree
Phaseolus vulgaris	Fabaceae	-	-	-	-	-	-	3	7500	1	Herb
Phytolacca dodecandra	Phytolaccaceae	15	37500	1	14	8750	4	-	-	-	Herb
Plantago lanceolata	Plantaginaceae	-	-	-	9	11250	2	33	20625	4	Herb
Psidium guajava	Myrtaceae	-	-	-	9	75	3	136	850	4	Tree
Ricinus communis	Euphorbiaceae	4	50	2	6	75	2	37	154	6	Shrub
Rumex nepalensis	Polygonaceae	6	15000	1	-	-	-	-	-	-	Herb
Saccharum officinarum	Poaceae	-	-	-	-	-	-	6	150	1	Shrub
Salvia nilotica/Ocimum basilicum	Lamiaceae	-	-	-	-	-		6	15000	1	Herb
Senna septemtrionalis	Fabaceae	-	-	-	7	17500	1	-	-	-	Herb
Senna didymobotrya	Fabaceae	6	150	1	2	50	1	-	-	-	Shrub

Setaria megaphylla	Poaceae	-	-	-	26	32500	2	-	-	-	Herb
Sida schimperiana	Malvaceae	-	-	-	55	11 458	12	-	-	-	Herb
Sida rhombifolia	Malvaceae	26	7222	9	-	-	-	-	-	-	Herb
Snowdenia polystachya	Poaceae	200	5000	10	526	77 352	17	218	136250	4	Herb
Solanecio sp.	Asteraceae	-	-	-	-	-	-	1	25	1	Herb
Solanum incanum	Solanaceae	-	-	-	5	4166	3	-	-	-	Herb
Solanum tuberosum	Solanaceae	-	-	-	-	-	-	20	16666	3	Herb
Sorghum bicolor	Poaceae	-	-	-	135	1688	2	-	-	-	Herb
Syzygium guineense	Myrtaceae	-	-	-	-	-	-	2	50	1	Tree
Tinospora cordifolia	Menispermaceae	141	88125	4	-	-	-	-	-	-	Herb
Trifolium rueppellianum	Fabaceae	-	-	-	39	97500	1	-	-	-	Herb
Urera hypselodenron	Urticaceae	1	25	1	11	138	2		-	-	Shrub
Urtica simensis	Urticaceae	-	-	-	-	-	-	34	42500	2	Herb
Vernonia auriculifera	Asteraceae	-	-	-	92	460	5	-	-	-	Shrub
Vernonia leopoldi	Asteraceae	18	450	1	-	-	-	-	-	-	Shrub
Vicia sativa	Fabaceae	6	15000	1	-	-	-	-	-	-	Herb

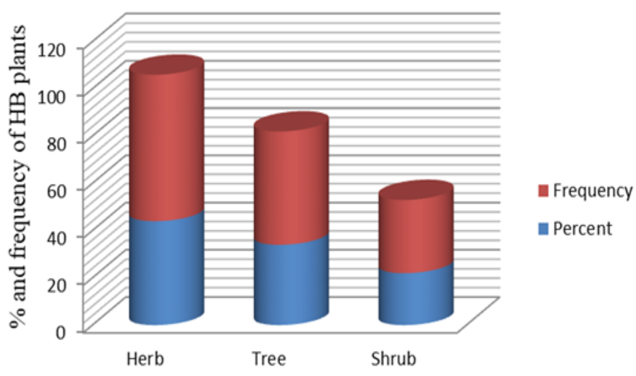

Figure 4. Growth forms of bee plant species

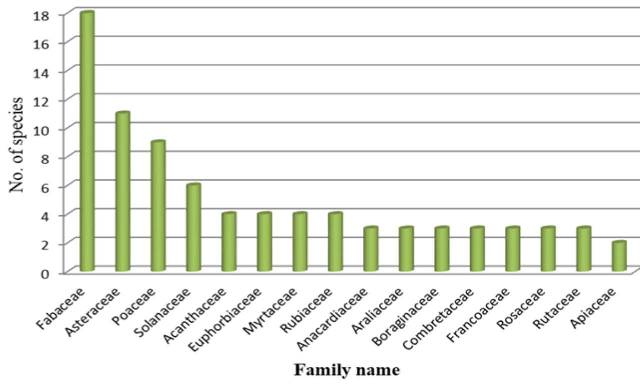

Figure 5. Number of species within each family

Table 5. Shannon diversity indices of honeybee plant species in ecosystems

Agro-ecosystem	Richness	Shannon	H'max (lns)	Shannon Evenness =H'/lnS
Highland	50	2.7	3.9	0.6
Lowland	47	2.6	3.8	0.6
Midland	59	3	4.1	0.7

Note: S: Number of species, H'max: Maximum diversity, H': Shannon index

Species diversity, richness and evenness of honeybee plant species

The Shannon diversity index analysis revealed that the midland agro-ecosystem had the most species diversity in sample plots compared to the highland and lowland agro-ecosystem. The species diversity in highland and lowland ecosystems was the same. The species richness varied by ecosystem. Midland ecosystem had comparatively the most species (59 species in 34 families), followed by highland (50 species in 29 families) and lowland ecosystem (47 species in 26 families) (Table 5). In the study areas, the midland ecosystem had the highest evenness, followed by the highland and lowland ecosystem. The Shannon diversity index of the study area was found to be 2.8, which fell in the range between 1.5 and 3.5 (Kent and Coker 1992). This indicated the area possessed a good plant density. The Shannon evenness value (0.6) showed that the honeybee plant species counted in the quadrats were evenly distributed in the sample plots and sites.

Discussion

The species of bee plants indicated by beekeepers through survey were more or less comparable to those found by plant inventory and pollen analysis. This has demonstrated that beekeepers' indigenous knowledge is significant for bee plant inventory results. *Vernonia* spp., *C. africana*, and *G. scabra* were the most abundant plant species in the highland, midland, and lowland, respectively. The most frequently indicated bee floral species by beekeeprers were *Vernonia* spp, *C. arabica*, *C. macrostachyus*, and *G. scabra* with 90 (100%), 83 (92.2%), 77 (85.6%) and 73 (81%) rate, respectively. The highest bee floral plant species has been known as the best indicators of adaptation to the area and climatic condition (Wubie et al. 2014). However, no single bee floral plant species has been identified by beekeeper respondents in the midland. This demonstrated that the midland has an overlapping agro-ecosystem in terms of bee flora plant species or vegetation distribution. According to the survey results, trees (62.5%) were the most important source of bee forages, followed by herbs (25%) and shrubs (12.5%). This finding is consistent with the findings of Kebede and Gebrechirstos (2016) and Haftom et al. (2013) in Tigray, who found trees to be a major source of feed for honeybees. The current survey findings, however, contradict the findings of Teklay (2011), who reported that herbs were the most common floral plant species. This finding variation might link with the changes in geographical location, soil type and climatic situation.

Honey yields were mainly harvested twice a year by 68.9% of beekeepers in different agro-ecosystems of the study area. This result is consistent with the study done by Shegaw and Giorgis (2021), which found that there were two main harvesting seasons. Honeybee plants are present at different periods of the year because plant flowering times vary depending on species, topography, climate, and farming practices (Rijal et al. 2018). The major flowering months of the study area were September, October, February, March, April, May and June. Bareke and Addi (2019) and Zeleke et al. (2019) conducted comparable studies in the Gera forests and selected parts of South Nations Nationalities and Peoples of Ethiopia, respectively. On the other hand, according to beekeepers who participated in the survey, the study area's dearth periods were August, July, and January. Another scholar, Shegaw and Giorgis (2021) carried out an analogous study in selected areas of the South Nations Nationalities and Peoples of Ethiopia. A drought period can cause the depletion of stored food inside the hive, which has a negative impact on honeybee productivity. Therefore, beekeepers should know the dynamics of honeybee colonies in accordance with bee floras, flowering periods, and duration of flowering times in different agro-ecosystem. Almost all beekeepers in the study area were familiar with the honeybee colony dynamics conditions. This finding agrees with the results of the study conducted by Fichtl and Admassu (1994), Lemessa (2006) and Teklay (2011). Beekeepers identified bee flora depending on the intensity of flowers visited by honeybees. The knowledge gained in identifying bee flora assists beekeepers in recognizing the honey harvesting season and managing the beehives. The identification of flora calendar assists beekeepers in planning various beekeeping activities (Genet 2002). In fact, not all honey bee plants are equally important in the lives and honey production of different bee species. The most frequently identified poisonous plant species in the study area, according to current findings, was *E. cotinifolia* (key abeba). In the Kaffa zone of southwest Ethiopia, analogous findings were reported by Addi (2018). *E. cotinifolia* is a shrub that belongs to the family Euphorbiaceae, which bears flowers at different months of the year. This plant is easy to adapt and propagate by cutting, and it also acts as a living fence in the study area.

The highest pollen grains were collected in October and November because the majority of plant species bloom following the long rainy season (June to August). The lowest pollen loads, on the other hand, were recorded in July and August because rain impairs honeybees' ability to fly, which in turn lowers their ability to collect pollen. Low temperatures may also impede the growth and flowering of bee plant species, which would reduce pollen production and nectar secretion. The findings are consistent with those of studies carried out in the Kaffa zone, southeast Oromia zone, and central Ethiopia by Lemessa and Addi (2009) and Bareke and Addi (2020), respectively. Contrary to the current findings, Wubie et al. (2014) reported that most pollen grains were collected during the main rainy season. This might occur since the flowering period differs with different agro-ecosystem areas.

In general, a total of one hundred forty-one pollen and/or nectar source honeybee plant species belonging to sixty-two families were discovered based on the survey, pollen load collection and plant inventory data results. Herbs, trees, shrubs, and grass were among the plant growth forms that honeybees use as forages. Herbs were the most dominant bee flora, accounting for 62 (44%) of a total of 141 honeybee plant species, followed by trees at 48 (34%) and shrubs at 31 (22%), respectively. This finding is consistent with previous findings, as herbs are the most dominant bee flora plants in different parts of Ethiopia (Teklay 2011; Abebe and Temam 2016; Addi 2018; Bareke and Addi 2019; Bareke and Addi 2020). The predominant of herbs are due to disturbance and existence of gaps in the forest (Bareke and Addi 2019). The Fabaceae and Asteraceae families have the highest number of species, with eighteen and eleven species, respectively. The study carried out in the Gera forests also revealed that the Fabaceae family had the dominant species composition, followed by Asteracea, which is consistent with current findings (Mulugeta et al. 2015). This study was focused on the overall floristic composition of Gera forest rather than identifying specific species of honeybee flora.The present findings, on the other hand, contradict previous reports, as Asteraceae family has the highest species composition in Kaffa Zone and Gera forests (Addi 2018; Bareke and Addi 2019; Bareke and Addi 2020). Not all Fabaceae species are plants that attract honeybees. As a result, it is not a dominating honeybee plant family in different study sites. However, the Asteraceae family is the most common bee foraging family in many forest areas (Bareke and Addi 2020). The Asteraceae family's dominance may be ascribed to the ability of certain of its species to produce honey (Bareke and Addi 2019). The main sources of honeybee forages were wild 116 (82.3%) and cultivated 25 (17.7%). These findings indicated that majority of bee floral plant species were found in wild sources, since beekeepers had no practices to cultivate bee floral plant species. The best predictor of adaptation to the area and local conditions is thought to be the highest frequency of bee plant species. Due to their climate preferences for growth, Boraginaceae, Rubiaceae, Poaceae, and Myrtaceae were the most prevalent families in sample plots. Herbaceous plant species had a greater density value of plant species per plot than did trees and shrubs. This result is consistent with Wubie et al. (2014) findings. This is a result of lower seed sizes taking up a significant portion of the plots. The trees and shrubs density was lower due to desertification.

The majority of honeybee plant species were considered as the basic sources of both pollen and nectar in the study area. Forage sources (pollen/nectar) were confirmed with published and pollen specimen accounts. The present study revealed that bee plant species were the main source of both pollen and nectar, rather than a single source of nectar or pollen. The findings also demonstrated that species of pollen-producing plants are more numerous than nectar-producing ones. This finding is aligned with those reported by Bareke and Addi (2020). Nectar and pollen are used for honey production and colony multiplication, respectively. Not all honeybee plants are similarly significant to bees and honey production. Only 16% of flowering plants are the origins of the majority of the honey in the world (Crane 1990). This shows that there are only a handful of significant honey source plants in each geographical area.

The analysis of bee forage diversity, richness, and evenness was estimated in different agro-ecosystem systems using the Shannon-Wiener diversity index. The midland agro-ecosytem moderately had the most species diversity, richness, and evenness compared to the highland and lowland agro-ecosystems. These findings, however, contradicted the findings of Wubie et al. (2014), who indicated that highland agro-ecology had more species diversity and richness than midland and lowland ecological systems. This variation could be attributed to differences in the geographical location, soil type, and climatic conditions of the study areas. Nevertheless, this doesn't mean that areas with a higher quantity of plant diversity are good for honey production, since the productivity of the beekeeping sector is reliant on the abundance and density of plants. The Shannon diversity index and evenness were found to be 2.8 and 0.6, respectively. This finding indicated that the study area possessed good plant density evenly distributed in the sample plots and sites. The higher the evenness and Shannon index values, the more even the species and diversity in the ecosystem or plots. The current finding further supported the notion that the species diversity and evenness in sample plots fell within acceptable bounds.

According to current findings, the study area has a diverse range of floral species, which may aid in the production of honey for national and international markets. A total of one hundred forty-one pollen and/or nectar source honeybee plant species belonging to sixty-two families were identified in the study area. The Fabaceae and Asteraceae families have the highest number of species. Herbaceous plant species had a greater density value of plant species per plot than did trees and shrubs. And honeybees prefer herbaceous floral plant species such as weeds and a few trees and shrubs to produce honey. Two main flowering periods of honeybee plants were followed by two honey harvesting periods indicated in the study area. The identification of bee plant species, as well as their floral calendar, aids beekeepers in planning various beekeeping activities. Therefore, beekeepers should follow floral calendar of honeybee plants to exploit the potential of the area for honey production.

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