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Research Article

Identification and characterization of honeybee flora in Jimma Zone, Ethiopia

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Abstract: *Due to the existence of diverse floral resources and favorable ecological conditions, Ethiopia is still one of the top ten natural honey producers worldwide. The study was conducted to identify and characterize the phenology and pollen potential of major bee forages in the various Agro-ecological conditions of Jimma zone. A total of 90 beekeepers were purposefully selected from three districts and interviewed using semi-structured questionnaire. The density and abundance of flowering plants were determined using sixty main quadrant sampling techniques. In addition, sixty-six pollen specimens were collected for one year using pollen traps at seven-day intervals and were also traced back to plant species level under a light microscope. The diversity of the bee flora was determined using the Shannon-Wiener diversity index. Based on survey, pollen load collection, and plant inventory data, the study has revealed the presence of 141 pollen and/or nectar-source honeybee plant species belonging to 62 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. Herbaceous plant had a greater density value of plant species per plot than did trees and shrubs. 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 Euphorbiaceae 4 (2.8%) in the study area. One hundred fifteen (81.6%) bee forage species 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. The midland Agro-ecology relatively has the highest species diversity, richness and evenness compared to the highland and lowland Agro-ecologies. Two main flowering periods of honeybee plants were followed by two honey flow season. Therefore, beekeepers should follow floral calendar of honeybee plants to exploit the potential of the area for honey production.*

Keywords: Agro-ecology, flora resources, floral calendar, flowering period

1. Introduction

Apiculture is a livestock industry that contributes significantly to the national and international economies of a country, mainly in Africa. Ethiopia is still one of the top ten natural honey producers worldwide due to the existence of diverse floral resources and favorable ecological conditions (Fitchl 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. 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 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 (Facade and Paul, 2006).

Ethiopia has abundant natural and cultivated flora as well as diverse agro-ecological and climatic conditions that are ideal for beekeeping. The presence of a large number of honey plants is important for the country's honeybee colonies, production, and productivity. The botanical composition of natural vegetation differs depending on the Agro-ecology, climate, and soil type (Gebretsadik, 2016). The type and quantity of flora present determines productivity and reproduction performance of honeybees (Amssalu, 2007). Oromia is one of the Federal Republic of Ethiopia's regional states that is rich in natural resources and has favorable climatic conditions for improved beekeeping development. The region has virgin forests with a 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-ecological, 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-ecological zones of the country (Admasu *et al*., 2004; Amssalu, 2004). Identification and documentation of bee forages and their flowering calendar is critical for the sub-sector's 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 flowering period, nectar and pollen production, and honeybee plant availability in a specific area are all determined by agro-ecology and season. Therefore, assessing the different Agro-ecological 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 (Pearson and Braiden, 1990). The study's overarching goal was to characterize and document major bee forages contributing to honey production, as well as to develop an appropriate flora calendar for effective bee management in various Agro-ecological conditions of the Jimma zone.

2. Materials and Methods

2.1. Description of the study area

The study was conducted in beekeeping potential areas of the Jimma zone of Oromia regional state, which geographically lies at a latitude of about 7013’-8 056'N and a longitude of about 35052'-

37037'E. 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 ecological differences and beekeeping potential. Agro-ecological representation is used to exploit bee flora species in different ecologies in the study area.

2.2. Honeybee flora inventory

Three kebeles were selected from each district depending on their Agro-ecological 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 harvest per year and presence of poisonous plants. Semi-structured questionnaires were used to collect the primary data from respondents. 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. During data collection, the types of honeybee forage, honey flow season, plants with adverse effects, swarming seasons, and management practices were all considered.

2.3. Pollen sample collection and laboratory analysis

The total of 18 honeybee colonies was established in nine different locations across three districts of the study area in different Agro-ecologies. 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 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, and the fresh and dry pollen pellets were weighed and sorted by color. Each sorted pollen samples were identified at generic and species level under light microscope following diluting with ether solution. Using prepared pollen reference materials, reference books, pollen atlases, plant species were identified from each type of pollen by comparing the shape, size, and apertures of the pollen. Pollens that we couldn't identify botanically using either analysis technique have been labeled as "unidentified".

2.4. Honeybee flora species composition and diversity

Assessment of plant species composition and diversity were performed in purposively selected districts based on the beekeeping potential. For vegetation analysis using quadrant sampling techniques, two representative kebeles were chosen from each district based on vegetation coverage and ecological difference. The diversity and composition of honeybee plants were determined according to Tesfaye *et al*. (2013) plant density determination method. The quadrant/plot size varied depending on vegetation types. Honeybee plants were classified as trees, shrubs, and herbaceous. Tree and shrub sampling plots were 20m × 20m in size, whereas herbaceous plant sampling plots were 2m x 2m in a two-kilometer radius every 0.1km 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 quadrants of 2m x 2m 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-ecologies. Then plant species within quadrants were counted for the assessment of plant density and frequency at specific sampling sites. Honeybee flora species abundance was defined and computed in all quadrants, and density was calculated in hectares. Plant specimens were collected during flowering seasons with necessary botanical features like leaves, flowers and portion of stem. The collected specimens were pressed, identified and then compared to the published report at the Holeta Bee Research Center.

2.5. 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 for non-sample-size-dependent measure of species diversity (Ramirez-Arriaga *et al*., 2011).

Shannon index (H') $= \Sigma\ (pi * lnpi)$ [1]

Where, H' is Shannon index, pi is proportion of individual species and ln is log base n.

$Evenness\ (J) = \frac{H'}{H'max} = \frac{H'}{INS}$ [2]

Where, H' is Shannon diversity index, H'max = lns where S is the number of species, ln = log basen. The value of evenness is found between zeros to one (Kent and Coker, 1992).

2.6. Statistical analysis

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

3. Results and Discussion

3.1. Major honeybee plant species identified by beekeepers

A total of 39 pollen and/or nectar source plant species belonging to 23 families were identified during the survey work (Table 1). The species of bee plants reported 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.

The most frequently reported bee floral species by beekeepers were *Vernonia spp*, *Coffea arabica*, *Croton macrostachyus*, and *Guizotia scabra* with 90 (100%), 83 (92.2%), 77 (85.6%) and 73 (81%) rate, respectively. The most 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 bee flora plant species or vegetation distribution.

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 beekeeper respondents, 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 to the findings of Teklay (2011), who reported that herbs are the most common floral plant species. These variations might link with the changes in geographical location, soil type and climatic situation.

The foremost 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. Honeybee plant species reported by beekeepers during the survey were categorized as very good, good, and poor based on their abundance in the study area (Table 1). Most of the bee floral species identified through the survey were categorized as good in their abundance.

Coffea arabica, *Croton macrostachyus*, *Vernonia Spp.*, *Guizotia scabra*, *Eucalyptus camaldlensis*, *Coffea arabica Cordia africana*, *Mangifera indica*, and *Combretum molle* were the most common honeybee plant species identified by beekeepers in different agro-ecologies (Table 1). The dominant honeybee plant species in the highland were *Vernonia Spp.*, *Schefflera abyssinica*, *Croton macrostachyus*, *Coffea arabica*, and *Bidens spp.*, while the most frequently visited bee floral species in lowland ecology were *Cordia africana*, *Guizotia scabra*, Combretum *molle*, *Eucalyptus camaldlensis*, *Bidens spp., and Coffea arabica*. On the other hand, *Guizotia scabra*, *Vernonia Spp.*, *Coffea arabica*, *Croton macrostachyus*, and *Bidens spp.*, were the most abundant floral plant species in midland agro-ecology based on survey results. *Vernonia Spp.*, *Cordia africana, and Guizotia scabra* were the most abundant plant species in the highland, midland, and lowland, respectively. Frequently indicated bee floral species by beekeepers were *Vernonia spp.*, *Coffea arabica*, *Croton macrostachyus*, and *Guizotia 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-ecology is *Vernonia spp*., *Schefflera abyssinica* and *Combretum molle*.

About 69.9% of beekeepers harvested honey yields twice a year, while 17.8% of beekeepers harvested honey yields three times in different agro-ecologies of the study area. This result is consistent with the study done by Shegaw and Giorgis (2021), who found that there are 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 average honey yields of frame hives in highland, lowland, and midland were 25.3, 23.3, and 30.2 kg respectively. The major honey flow seasons in the study are October to December, February to April, and May to June (Figure 1). The maximum and minimum flowering duration of bee plant species were ninety and seven days, respectively. *Croton macrostachyus*, *Vernonia spp*., *Eucalyptus camaldlensis*, *Guizotia scabra*, and *Trifolium spp*. had the longest flowering periods and offered a steady supply of nectar and pollen to honeybees on the hunt. 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 respondents, the study areas dearth periods were August, July, and January. Shegaw and Giorgis (2021) conducted similar study in selected areas of the Southern 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-ecologies. Almost all beekeepers in the study area were familiar with the honeybee colony dynamics conditions. This findings agrees with the study conducted by Lemessa (2006), Fichtl and Admassu (1994) and Teklay (2011) in colony dynamics conditions. Beekeepers were identified as bee flora depending upon 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).

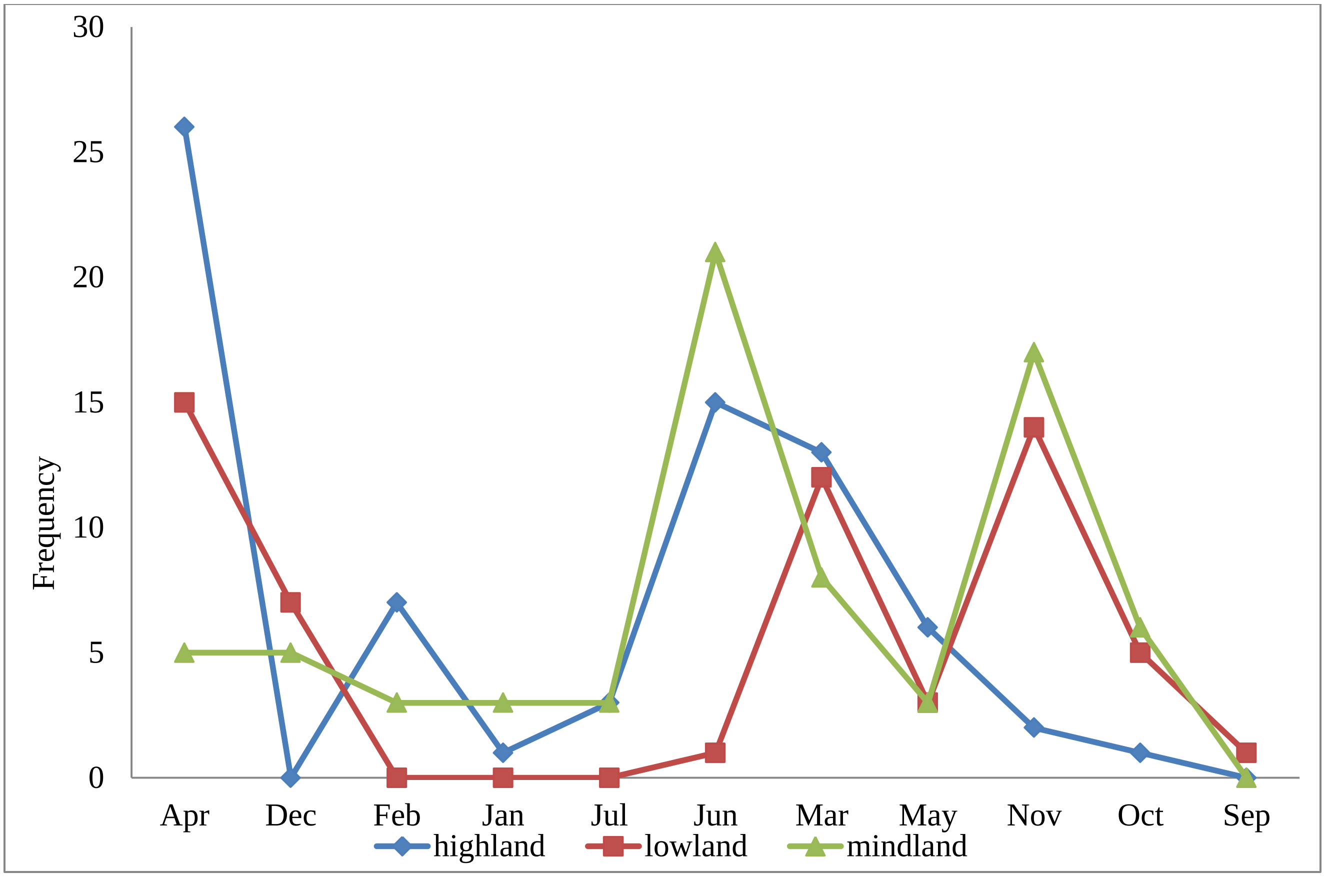

Figure 1: Honey flow month in different agro-ecologies

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	Pollen/ Nectar	Feb, Mar	60
Bisana	*Croton macrostachyus*	Euphorbiaceae	2	Tree	Pollen/ Nectar	Jun, May, Aug, Apr	90
Girawa	*Vernonia Spp.*	*Asteraceae*	1	Tree	Nectar	Dec-Mar	90
Tufo	*Guizotia scabra*	Asteraceae	2	herb	Pollen/ Nectar	Aug-Dec	90
Bahrzaf	*Eucalyptus camaldlensis*	*Myrtaceae*	3	Tree	Pollen/ Nectar	Year round	90
Wanza	*Cordia africana*	*Boraginaceae*	2	Tree	Pollen/ Nectar	Aug, Jul, Sep	60
Abalo	*Brucea antidysenterica Fresen.*	Simaroubaceae	3	Tree	Pollen/ Nectar	Apr,Mar	15
Avocado	*Persea americana*	Lauraceae	2	Tree	Pollen	Sep, Oct, Jan, Feb,	90

						Apr	
Mango	*Mangifera indica*	*Anacardiaceae*	3	Tree	Pollen/ Nectar	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, Jn, Feb, Mar	90
Rejii	*Vernonia rueppellii sch.*	*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 sp.*	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	Mar	20

					/nectar		
Ruze	*Oryza sativa*	Poaceae	3	Herb	Pollen	Sep, Oct	30
Sesame	*Sesamum indicum*	Pedaliaceae	2	Herb	Pollen /nectar	Mar, May, Jun, Sep	60
Sole	*Olinia rochetiana*	Penaeaceae	2	Tree	Pollen/nectar	Sep, Mar	60
Bedesa	*Syzygium guineens*	*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

3.2. Plants poison to honeybees

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 *Euphorbia cotinifolia* (*Key abeba*). The result showed that 77.2% of beekeepers were aware of the presence of poisonous plants for honeybees. About 27.8% of the beekeepers have no awareness of the availability of poisonous honeybee plants in their surrounding areas. In the Kaffa zone of southwest Ethiopia, similar findings were reported by Addi (2018), as most of the beekeepers were aware of the presence of poisonous plants for honeybees. *Euphorbia 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. It is mainly found in highland and midland Agro-ecology. The major flowering months of *Euphorbia cotinifolia* species are September to November, February to April, and May to June in the study areas.

3.3. 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., coffea arabica* and *eucalyptus spp.* were the major pollen-source for honeybees (Figure 2). On the other hand, *Bersama abyssinica, Olea afriicana, Syzygium guineense (Willd.) DC* and *Syzyjium spp*. were the minor pollen sources for honeybees. The current study found that the highest proportion of pollen grains was collected in October (46.3%) and November (14.6%). This is due to the fact that 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 Bareke and Addi (2020), Lemessa and Addi (2009), respectively, in the collection of pollen grains in October and November. Contrary to the current findings, Wubie *et al.* (2014) reported that the most pollen grains were collected during the main rainy season. This might occur since the flowering period differs with different agro-ecologies.

Figure 2: Major honeybee flora species identified through pollen analysis

Table 2: Bee plant species identified from pollen analysis and pollen 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
Euclyptus	Myrtaceae	Tree	Pollen/nectar	Dec-Jan, Oct-Nov
Bidens spp	Asteraceae	Herb	Pollen/nectar	Oct-Jan
Trifoluma spp	Fabaceae	Herb	Pollen/nectar	Oct, Dec-Jan
Parkinsonia aculeuta	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
Calesulpinia	Francoaceae	Herb	Pollen/nectar	Dec
Calesulpinia decaptal	Francoaceae	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
Rubuytmaesolonceolata	not id	-	pollen	Mar
Syzyjium spp	Myrtacea	Tree	pollen	Oct

3.4. Honeybee flora species abundance and density

Density and frequency of honeybee floral species found in each quadrant have been summarized in Table 3. During the plant inventory investigation, a total of 98 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 honeybee plant species encountered in quadrant samples. 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) and Addi *et al*. (2004), who found that herbaceous plant species had a higher density value per plot than trees and shrubs.

The most common or top ten floral honeybee plant species in highland sample plots/quadrants were *Cynoglossum lanceolatum Forssk*, *Coffea arabica*, *Isoglossa species*, *Snowdenia polystachya* (Fresen.) *Pilg*, *Pennisetum glaucum (Linn.) R Br*, *Desmodium species*, *Tinospora cordifolia*, *Acanthus eminers C.B Clarke*, *Eucalyptus camaldlensis* and *Cyclamen purpurascens* (Table 4). *Cynoglossum lanceolatum Forssk*, *Snowdenia polystachya (Fresen.) Pilg*, *Bidens spp.*, *Sorghum bicolor*, *Isoglossa spp.*, *K. pinnata*, *Erythrina abyssinica*, *Euphorbia tirucalli*, *Vernonia auriculifera Hiern and Lippia adoensis Hochst. ExWalp* were the most frequent honeybee plant species in lowland ecology

(Table 4) whereas *Cynoglossum lanceolatum Forssk, Eucalyptus camaldlensis, Colocasia esculenta, Snowdenia polystachya (Fresen.) Pilg, K. pinnata, Erica spp., Psidium guajava, Arum maculatum and Guizotia scabra* were the dominant honeybee plant species in midland sample plots (Table 4).

Table 3: Honeybee plant species density and frequency in sample quadrants

Local name	Scientific name	Family	Plant type	Plant count	Plant density	Plot observed
Ambebesa/sesa	*Albizia gummifera*	Fabaceae	Tree	44	267	9
Arenchi	*Pavonia urens*	Malvaceae	Herb	89	8663	8
Bahrzaf	*Eucalyptus camaldlensis*	Myrtaceae	Tree	704	4689	8
Banana	*Musa acuminate*	Musaceae	Tree	82	2050	3
Bisana	*Croton macrostachyus*	Euphorbiaceae	Tree	34	174	12
Buna/Coffee	*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	*Isoglossa species*	Acanthaceae-N	Herb	464	69074	50
Emo	*Colocasia esculenta*	Araceae	Herb	352	1996	10
Girawa	*Vernonia Spp.*	Asteraceae	Tree	77	261	22
Girnche/chifrig	*Sida schimperiana Hochst. ex A. Rich.*	Malvaceae	Herb	222	2500	19
Kello/adey abeba	*Bidens spp.*	Asteraceae	Herb	497	37499	30
Metene	*Cynoglossum lanceolatum Forssk.*	Boraginaceae	Herb	2514	68281	110
Muja	*Snowdenia polystachya (Fresen.) Pilg*	Poaceae	Herb	944	141250	31
Rejii	*Vernonia auriculifera Hiern*	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 (Willd.) Benth*	Rutaceae	Shrub	22	244	7
Abayi/qalawa	*Maesallanceolataforssk*	Myrsinaceae	Tree	14	200	4
Arebe duberti	*Carduus schimperi Sch. Bip*	Asteraceae	Herb	58	42916	7
Birbira	*Millettia ferruginea*	Fabaceae	Tree	7	113	3
Bosoke	*Kalanchoe sp.*	Crassulaceae	Herb	95	52000	9
Chat	*K. 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 Carinta A.br.*	Brassicaceae	Herb	15	37500	2
Haallaal	*Urera hypselodenron (A.Rich) wedd*	Urticaceae	Shrub	44	83750	4
Kontir	*Caesalpinia decapetala*	Fabaceae	Shrub	65	1116	4
Korch	*Erythrina abyssinica*	Fabaceae	Tree	143	1131	6
Mango	*Mangifera indica L.*	Anacardiaceae	Tree	2	50	2
Qortobi	*Plantigo lanceolata L.*	Plantaginaceae	Herb	42	31875	6
Sanaa maki	*Senna didymobotrya (Fresen.) Irwin*	Fabaceae	Shrub	8	200	2

	and Barneby					
Sindedo	*Pennisetum thunbergii Kunth*	Poaceae	Herb	18	45000	2
Sokoro	*Acanthus eminers C.B Clarke*	Acanthaceae	Herb	97	681	5
Ulaga	*Ehretia cymosa Thonn.*	Boraginaceae	Tree	5	58	4
Wanza	*Cordia africana*	Boraginaceae	Tree	17	148	9
Zeytuna	*Psidium guajava*	Myrtaceae	Tree	145	925	7
Adenguare	*Phaseolus vulgaris L*	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 Quart.-Dill. and A. Rich.*	Asclepiadaceae	Shrub	30	375	2
Apple	*Malus pumila*	Rosaceae	Shrub	2	50	1
Asangira	*Datura stramonium L.*	Solanaceae	Herb	9	11250	2
Askira	*Millettia ferruginea (Hochst.) Bak*	Fabaceae	Tree	15	63	6
Avocado	*Persea Americana*	Lauraceae	Tree	5	25	5
Baddessa/Dokima	*Syzygium guineens*	Myrtaceae	Tree	2	50	1
Besobila /kefo	*Salvia nilotica/Ocimumbasilicum*	Lamiaceae	Herb	6	15000	1
Boqqo	*Bersma abyssinica*	Melianthaceae	Tree	1	25	1
Bosoka	*Eriobotrya japonica*	Rosaceae	Tree	1	25	1
Butte	*Ammocharis tinneana (Kotschy and Peyr.) Milne-Redh. And Schweick*	Amaryllidaceae	Herb	8	10000	2
Cassava	*Euphorbiaceae*	Manihot esculenta	Shrub	124	1550	2
Cheka	*Calpurnia aurea (Aiton) Benth*	Fabaceae	Tree	4	100	1
Chibo	*Vernonia leopoldi*	Asteraceae	Shrub	18	450	1
Damisa	*Centella asiatica*	Apiaceae	Herb	7	17500	1
Dhumuga	*Justicaschimperiana(Hochst.ex.Nees) T. Andres*	Acanthaceae	Shrub	16	400	1
Potato	*Solanum tuberosum*	Solanaceae	Herb	20	16666	3
Dobbi/sama	*Urtica simensis steud.*	Urticaceae	Herb	34	42 500	2
Enselal	*Foeniculum vulgare Mill/Anethum graveolens L.*	Apiaceae	Herb	2	5000	1
Enset	*E. ventricosum*	Musaceae	Shrub	33	413	2
Girar	*Acacia spp.*	Fabaceae	Tree	3	75	1
Gomera	*Capparis tomentosa Lam.*	Capparidaceae	Shrub	1	25	1
Guriyo	*Tinospora cordifolia*	Menispermaceae	Herb	141	88125	4
Harbu/shola	*Ficus sur Forssk.*	Moraceae	Tree	2	50	1
Hidda bofa	*Momordica foetida (Ao) Schumach*	Cucurbitaceae	Herb	1	25	1
Hiddaa lafaa	*Dregea schimperi (Decne.) Bullock*	Asclepiadaceae	Herb	8	6666	3
Hiddi	*Solanum incanum L.*	Solanaceae	Shrub	5	4166	3
Jajjab	*Setaria megaphylla (Steud.) Th. Dur. and Schinz.*	Poaceae	Herb	26	32500	2

Karaba	*Sida rhombifolia L.*	Malvaceae	Herb	26	7222	9
Kase	*Lippia adoensis Hochst. ex Walp*	Verbenacae	Herb	86	107,500	2
Kishkishe	*Senna septemtrionalis (Viv.) Irwin and Barneby*	Fabaceae	Herb	7	17500	1
Kunche	*Chenopodium album*	Amaranthaceae	Herb	21	17500	1
Kusaye	*Lantana trifolia L.*	Verbenaceae	Shrub	2	50	1
Lochisa	*Bersama abyssinica*	Melianthaceae	Herb	35	875	1
Mixoo/dido/di du	*Galiniera saxifrage (Hochst.) Birdson*	Rubiaceae	Shrub	2	50	1
Mulberry	*Morus alba*	Moraceae	Shrub	3	75	1
Nanaye	*Pennisetum glaucum (Linn.) R Br*	Poaceae	Herb	196	61 250	8
Pepper /berberi	*Capsicum annuum L.*	Solanaceae	Herb	18	4500	1
Qalawa/qaawa a	*Grewia mollis Juss*	Tiliaceae	Tree	1	25	1
Qumudu	*Nymphoides indica*	Menyanthaceae	Herb	41	34166	2
Raafu	*Kleinia grantii (Oliv. & Heiern) Hook.f.*	Asteraceae	Herb	17	21250	3
Ret/ Alovera	*Aloe debrana Christian (syn.A.berhana Reynolds)*	Xanthorrhoeacea e	Herb	17	42500	1
Rhodus	*Chloris gayana*	Poaceae	Herb	1	2500	1
Shajara	*Cyclamen purpurascens*	Primulaceae	Herb	80	33333	6
Shenkora	*Saccharum officinarum L.*	Poaceae	Shrub	6	150	1
Shultee	*Rumex nepalensis*	Polygonaceae	Herb	6	15000	1
Siddisa/wazma	*Trifolium rueppellianum Fresen.*	Fabaceae	Herb	39	97500	1
Siglu	*Fagaropsis angolensis (Engl.) Dale*	Rutaceae	Tree	6	150	1
Sorghum	*Sorghum bicolor*	Poaceae	Herb	135	1688	2
Suufi/suff	*Carthamus tinctorius*	Asteraceae	Herb	56	46666	3
Togo	*Dieliptera acanthaceae C.B.el*	Acanthaceae	Tree	10	25000	1
Tsid	*Juniperus procera Hochst. ex Endl*	Cupressaceae	Tree	40	1000	1
Uregessa	*Clausena anisata Benth*	Rutaceae	Tree	11	138	2
Vetch	*Vicia sativa*	Fabaceae	Herb	6	15000	1
Welensu	*Erythrina brucei*	Fabaceae	Tree	41	513	2
Yeriwo garo	*Solanecio sp.*	Asteraceae	Herb	1	25	1

Table 4: Honeybee plant species density and their frequency of occurrence

Scientific name	Family name	**Highland**			**Lowland**			**Midland**			
		Count	Density	Plot	Count	Density	Plot	Count	Density	Plot	Type
Vernonia Spp.	Asteraceae	48	100	12	10	42	6	19	119	4	T
Coffea arabica	Rubiaceae	425	1181	9	604	1373	11	710	1775	10	T
Croton macrostachyus	Euphorbiaceae	20	84	6	1	25	1	13	65	5	T
Vernonia rueppellii sch.	Asteraceae	27	135	5	92		5	14	167	3	S

Albizia gummifera	Fabaceae	8	67	3	1	25	1	35	175	5	T
Eucalyptus camaldlensis	Myrtaceae	112	933	3	3	75	1	589	3681	4	T
Malus pumila	Rosaceae	2	50	1	-	-	-	-	-	-	S
Acacia spp.	Fabaceae	3	75	1	-	-	-	-	-	-	T
Acanthus eminers C.B Clarke	Acanthaceae	93	581	4	-	-	-	4	100	1	H
Allamanda spp.	Apocynaceae.	-	-	-	13	16250	2	-	-	-	H
Aloe debrana Christi an (syn.A.berhana Reynolds)	Xanthorrhoeac eae	-	-	-	-	-	-	17	42500	1	H
Ammocharis tinnean a (Kotschy and Peyr.) Milne-Redh.and Schweick	Amaryllidaceae	8	10000	2	-	-	-	-	-	-	H
Arum maculatum	Araliaceae	-	-	-	-	-	-	121	30250	1	H
Bersama abyssinica	Melianthaceae		36	900	2	-	-	35	875	1	T
Bidens spp.	Asteraceae	32	13333	6	407	56 527	18	58	24166	6	H
Brassica Carinta A.br.	Brassicaceae	11	27500	1	--	-	-	4	10000	1	H
Caesalpinia decapetala	Fabaceae	23	192	3	-	-	-	42	924	1	S
Calpurnia aurea (Aiton) Benth	Fabaceae	-	-	-	-	-	-	4	100	1	T
Capparis tomentosa Lam.	Capparidaceae	-	-	-	1	25	1	-	-	-	S
Capsicum annuum L.	Solanaceae	-	-	--	-	-	-	18	4500	1	H
Carduus schimperi Sch. Bip	Asteraceae	26	16250	4	-	-	-	32	26666	3	H
Carissa spinarum	Apocynaceae	-	-	-	-	-	-	4	100	1	S
Carthamus tinctorius	Asteraceae	-	-	-	56	46666	3	-	-	-	H
Centella asiatica	Apiaceae	7	17500	1	-	-	-	-	-	-	H
Chenopodium album	Amaranthaceae	21	17500	3	-	-	-	-	-	-	H
Chloris gayana	Poaceae	1	2500	1	-	-	-	-	-	-	H
Clausena anisata (Wild.) Benth.	Rutaceae	2	50	1	9	56	4	22	276	4	S
Colocasia esculenta	Araceae	-	-	-	54	675	2	286	1021	7	H
Cordia africana	Boraginaceae	-	-	-	8	67	3	5	31	4	T
Cyclamen purpurascens	Primulaceae	80	33333	6	-	-	-	-	-	-	H
Cynoglossum lanceol atum Forssk.	Boraginaceae	997	51, 927	48	643	53 583	30	874	68281	32	H
Datura stramonium L.	Solanaceae	-	-	-	9	11250	2	-	-	-	H
Desmodiumspecies	Fabaceae	142	29583	12	-	-	-	104	21862	9	H
Dieliptera acanthaceae C.B.el	Acanthaceae	-	-	-	10	25000	1	-	-	-	T
Dracaena afromontana	Dracaenaceae	12	300	1	-	-	-	-	-	-	T
Dregea schimperi (D ecne.) Bullock	Asclepiadaceae	8	6666	3	-	-	-	-	-	-	H
E. ventricosum	Musaceae	-	-	-	-	-	-	33	413	2	S
Ehretia cymosa Thonn.	Boraginaceae	4	33	3	1	25	1	-	-	-	T
Eluesine folicofolia	Poaceae	4	10000	1							H
Erica genus	Ericaceae	1	2500	1	-	-	-	166	69166	6	H
Eriobotrya japonica	Rosaceae	-	-	-	1	25	1	-	-	-	T
Erythrina abyssinica	Fabaceae	38	475	2	105	656	4	-	-	-	T
Erythrina brucei	Fabaceae	-	-	-	-	-	-	41	513	2	T

esbania sesban	Fabaceae	28	116	6	1	25	1	43	538	2	S
Euphorbia tirucalli	Euphorbiaceae	41	512	2	101	842	3	-	-	-	S
Euphorbiaceae	Manihot esculent a	-	-	-	-	-	-	124	1550	2	S
Fagaropsis angolensis (Engl.) Dale	Rutaceae	-	-	-	-	-		6	150	1	T
Ficus sur Forssk.	Moraceae	2	50	1	-	-	-	-	-	-	T
Foeniculum vulgare Mill./Anethum graveolens L.	Apiaceae	-	-	-	-	-	-	2	5000	1	H
Galiniera saxifrage (Hochst.) Birdson	Rubiaceae	2	50	1	-	-	-	-	-	-	S
Grewia mollis Juss	Tiliaceae	1	25	1	-	-	-	-	-	-	T
Guizotia scabra	Asteraceae	4	10000	1	56	28000	5	10 2	29944	19	H
Isoglossa species	Acanthaceae	266	24629	27	120	30000	10	78	15000	13	H
Juniperus procera Hochst. ex Endl	Cupressaceae	-	-	-	-	-	-	40	1000	1	T
Justicaschimperiana(Hochst.ex.Nees)T. Andres	Acanthaceae	-	-	-	-	-	-	16	400	1	S
K. pinnata	Crassulaceae	-	-	-	109	1363	2	211	2638	2	S
Kalanchoe sp.	Crassulaceae	54	27000	5	41	25000	4	-	-	-	H
Kleinia grantii	Asteraceae	-	-	-	-	-	-	17	21250	2	H
Lantana trifolia	Verbenaceae	-	-	-	-	-	-	2	50	1	S
Lippia adoensis Hoc hst. Ex Walp	Verbenacae	-	-	-	86	107500	2	-	-	-	H
Maesallanceolatafor ssk	Myrsinaceae	9	75	3	-	-	-	5	125	1	T
Mangifera indica	Anacardiaceae	-	-	-	1	25	1	1	25	1	T
Millettia ferruginea (Hochst.) Bak	Fabaceae	5	63	2	15	63	6	2	50	1	T
Momordica foetida (Ao) Schumach	Cucurbitaceae	-	-	-	1	25	1	-	-	-	T
Morus alba	Moraceae	-	-	-	-	-	-	3	75	1	S
Musa acuminata	Musaceae	32	800	1	13	325	1	-	-	-	T
Nymphoides indica	Menyanthaceae	-	-	-	-	-	-	41	34166	3	H
Ocimum lamiifolium Hochst	Labiatae	-	-	-	12	11325	3	4	100	1	H
Pavonia urens	Malvaceae	41	5625	4	1	2500	1	47	538	3	H
Pennisetum glaucum (Linn.) R Br	Poaceae	196	61 250	8	-	-	-	-	-	-	H
Pennisetum thunbergii Kunth	Poaceae	-	-	-	-	-	-	14	35000	1	H
Periploca linearifolia Quart. Dill. & A. Rich.	Asclepiadaceae	-	-	-	-	-	-	30	37875	2	S
Persea Americana	Lauraceae	-	-	-	-	-	-	5	25	5	T
Phaseolus vulgaris L	Fabaceae	-	-	-	-	-	-	3	7500	1	H
Phytolacca dodecandra	Phytolaccaceae	15	37500	1	14	8750	4	-	-	-	H
Plantigo lanceolata L.	Plantaginaceae	-	-	-	9	11250	2	33	20625	4	H
Psidium guajava	Myrtaceae	-	-	-	9	75	3	136	850	4	T
Ricinus communis	Euphorbiaceae	4	50	2	6	75	2	37	154	6	S
Rumex nepalensis	Polygonaceae	6	15000	1	-	-	-	-	-	-	H
Saccharum officinarum L.	Poaceae	-	-	-	-	-	-	6	150	1	S
Salvia nilotica/Ocim umbasilicum	Lamiaceae	-	-	-	-	-		6	15000	1	H

Senna septemtrionalis (Viv.) Irwin and Barneby	Fabaceae	-	-	-	7	17500	1	-	-	-	H
Senna didymobotrya (Fresen.) Irwin and Barneby	Fabaceae	6	150	1	2	50	1	-	-	-	S
Setaria megaphylla (Steud.) Th. Dur. and Schinz.	Poaceae	-	-	-	26	32500	2	-	-	-	H
Sida schimperiana Hochst . Ex A. Rich.	Malvaceae	-	-	-	55	11 458	12	-	-	-	H
Sida rhombifolia L.	Malvaceae	26	7222	9	-	-	-	-	-	-	H
Snowdenia polystachya (Fresen.) Pilg	Poaceae	200	5000	10	526	77 352	17	218	136250	4	H
Solanecio sp.	Asteraceae	-	-	-	-	-	-	1	25	1	H
Solanum incanum	Solanaceae	-	-	-	5	4166	3	-	-	-	H
Solanum tuberosum	Solanaceae	-	-	-	-	-	-	20	16666	3	H
Sorghum bicolor	Poaceae	-	-	-	135	1688	2	-	-	-	H
Syzygium guineens	Myrtaceae	-	-	-	-	-	-	2	50	1	T
Tinospora cordifolia	Menispermaceae	141	88125	4	-	-	-	-	-	-	H
Trifolium rueppellianum Fresen.	Fabaceae	-	-	-	39	97500	1	-	-	-	H
Urera hypselodenron (A. Rich)	Urticaceae	1	25	1	11	138	2		-	-	S
Urtica simensis steud.	Urticaceae	-	-	-	-	-	-	34	42500	2	H
Vernonia auriculifera Hiern	Asteraceae	-	-	-	92	460	5	-	-	-	S
Vernonia leopoldi	Asteraceae	18	450	1	-	-	-	-	-	-	S
Vicia sativa	Fabaceae	6	15000	1	-	-	-	-	-	-	H

Note: T = Tree; S = Shrub; H = Herb; Density is per ha

3.5. Diversity and composition *of honeybee forages*

Herbs, trees, shrubs, and different species of grass are 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 (Figure 3). This finding is consistent with previous findings, as herbs are the most dominant bee flora plants in Kaffa Zone, Gera district (Addi, 2018; Bareke and Addi, 2019; Bareke and Addi, 2020), North Shewa zone of Amhara region (Abebe and Temam, 2016), and Tigray region (Teklay, 2011) The predominant of herbs are due to disturbance and existence of gaps in the forest (Bareke and Addi, 2019). 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 4). The Fabaceae and Asteraceae families have the highest number of species. The study conducted in the Gera forests also revealed that the Fabaceae family had the dominant species composition, followed by Asteracea, which is consistent with current findings (Mulgeta *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 species to produce honey (Bareke and Addi, 2019).

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. 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.

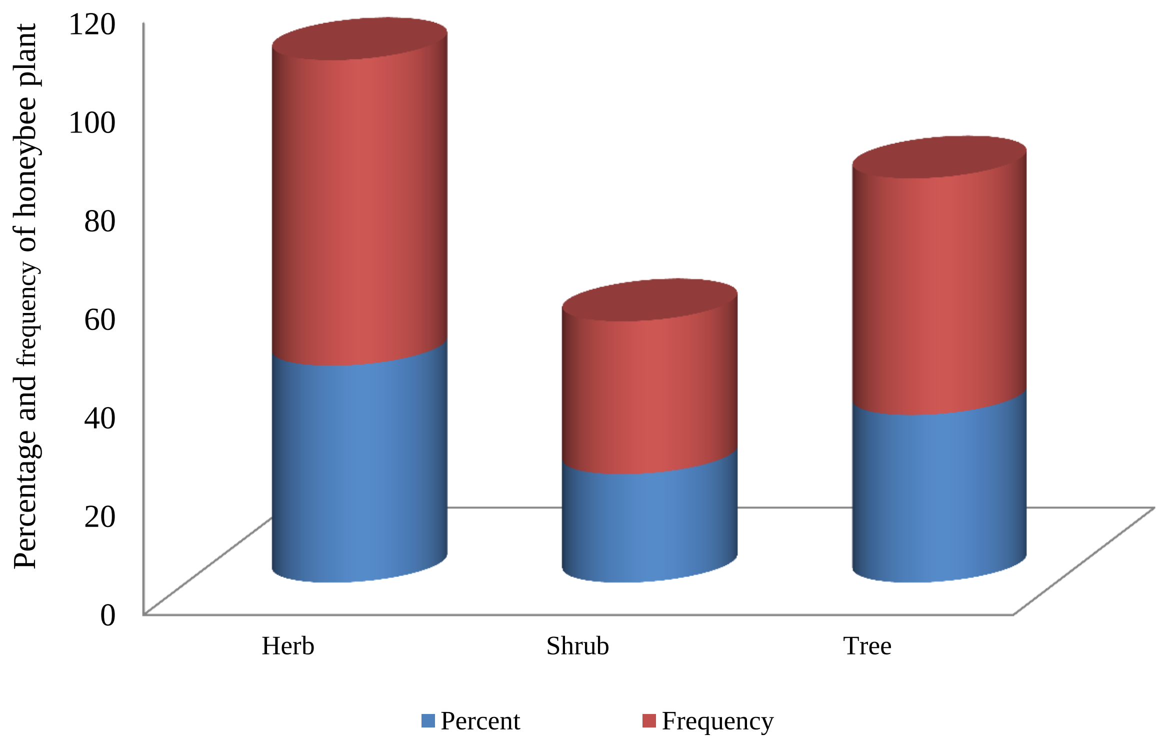

Figure 3: Growth forms of bee plant species

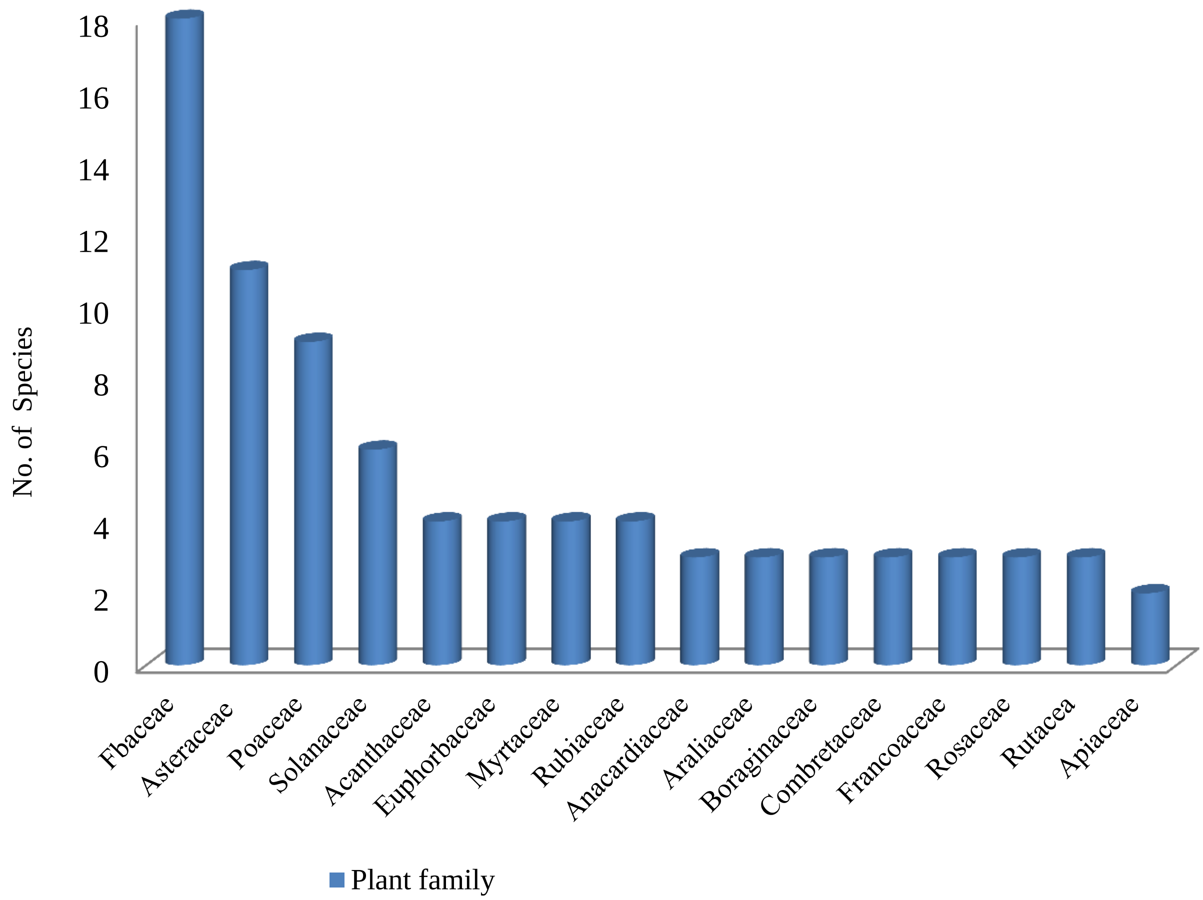

Figure 4: Number of species within each family

3.6. 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 (Table 5). The species richness varied by ecosystem. Midland ecology had comparatively the most species (59 species in 34 families), followed by highland (50 species in 29 families) and lowland (47 species in 26 families) ecologies. The midland Agro-ecology moderately has the most species diversity, richness, and evenness in sample plots compared to the highland and lowland agro-ecologies. 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. The higher the evenness and Shannon index values, the more even the species and the diversity in the ecology or plots. The current finding further supported the notion that the species diversity and evenness in sample plots fell within acceptable bounds of 1.5 and 3.5 (Kent and Coker, 1992).

Table 5: Shannon diversity indices of honeybee plant species

Agro ecology	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

4. Conclusion and Recommendation

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 141 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. There are two main flowering periods of bee plants and two main harvesting periods in the study area. The identification of bee plant species as well as their floral calendar helps the beekeepers in planning various beekeeping activities. Therefore, beekeepers should follow a floral calendar of honeybee plants to exploit the potential of the area for honey production.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

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