

Research Article

Diversity of Bee Floral Resources and Honey Production Calendar in Ethiopia's Southwest Shoa Zone

Tura Bareke , Kasim Roba , and Admassu Addi 

Oromia Agricultural Research Institute, Holeta Bee Research Center, Holeta, Ethiopia

Correspondence should be addressed to Tura Bareke; trbareke@gmail.com

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Bee flora resources are essential for the development of beekeeping. This study aimed to identify the diversity of key bee forage plants, establish honey harvesting calendars, and assess different types of monofloral honey in the area. Data collection methods included a bee plant inventory, pollen collection, and honey pollen analysis. A total of 122 plant species were identified as bee plants, with 44.26% being shrubs and 27.87% being trees. These bee plants were distributed across three districts, accounting for 37.40% of the plant species, indicating a broader ecological distribution than local species. Wonchi district exhibited the highest diversity of bee plants ($H' = 4.7$), followed by Waliso ($H' = 4.55$). Three honey harvesting periods were identified: November, January, and June. Additionally, three distinct types of monofloral honey were produced: *Erica arborea* honey in January, *Eucalyptus camaldulensis* honey in June, and *Guizotia scabra* honey in November. A shortage of bee forages was noted in February, March, July, and August across all districts. The southwest Shoa zone (comprising Wonchi, Waliso, and Amaya districts) shows potential for sustainable and commercial beekeeping based on the available bee flora resources. To ensure sustainability, it is crucial to maintain the existing bee flora and increase the propagation of multipurpose plant species. Additionally, on-farm demonstrations highlighting the importance of floral and honey calendars for effective colony management are recommended.

1. Introduction

Ethiopia is renowned for its high diversity of plant species [1, 2] and is a significant center of origin for many endemic plant species [3]. Out of the country's 6,000 species of higher plants, 647 (10.74%) are endemic [4]. Understanding the primary bee plant species and their flowering calendar in various agroecological zones is crucial for estimating the honey flow period, which is essential for effective beekeeping operations [5]. A flowering calendar provides beekeepers with a timetable that estimates the dates and durations of the blossoming periods of key honey and pollen-producing plants [5]. The flowering calendar and the seasonal cycles of honeybee colonies are interconnected, facilitating efficient seasonal colony management [6]. Beekeeping operations should align with the phenological patterns of local honey plants to ensure that the peak population size of bees occurs before or during the nectar flow, even though bee populations naturally increase when resources are abundant [7].

The variety in geography, climate, and plant habits results in differences in flowering plants, their blooming periods, and

nectar secretion potentials across different locations [8]. Consequently, honey flow and dearth seasons vary by region and altitude [9]. Beekeepers can maximize honey and other honeybee products by leveraging their extensive knowledge of the type, density, and quality of bee flora resources [10, 11].

Ethiopia holds significant potential for the growth of beekeeping [12], with the capability to produce 500,000 tons of honey annually. However, the current annual honey production is only 10.8% of this potential [13]. This shortfall is primarily due to the inadequate adoption of advanced beekeeping technologies and skills that enhance the quantity and quality of bee products, as well as a lack of information on colony management in relation to blooming calendars [10, 14].

The Oromia region boasts the highest forest coverage among Ethiopia's nine regions, encompassing 70% of the nation's forested areas [15]. This extensive forest cover significantly contributes to Oromia's status as the leading honey-producing region in Ethiopia, accounting for 41% of the country's honey production [16]. The southwest Shewa zone, similar to other parts of Ethiopia, shows great promise

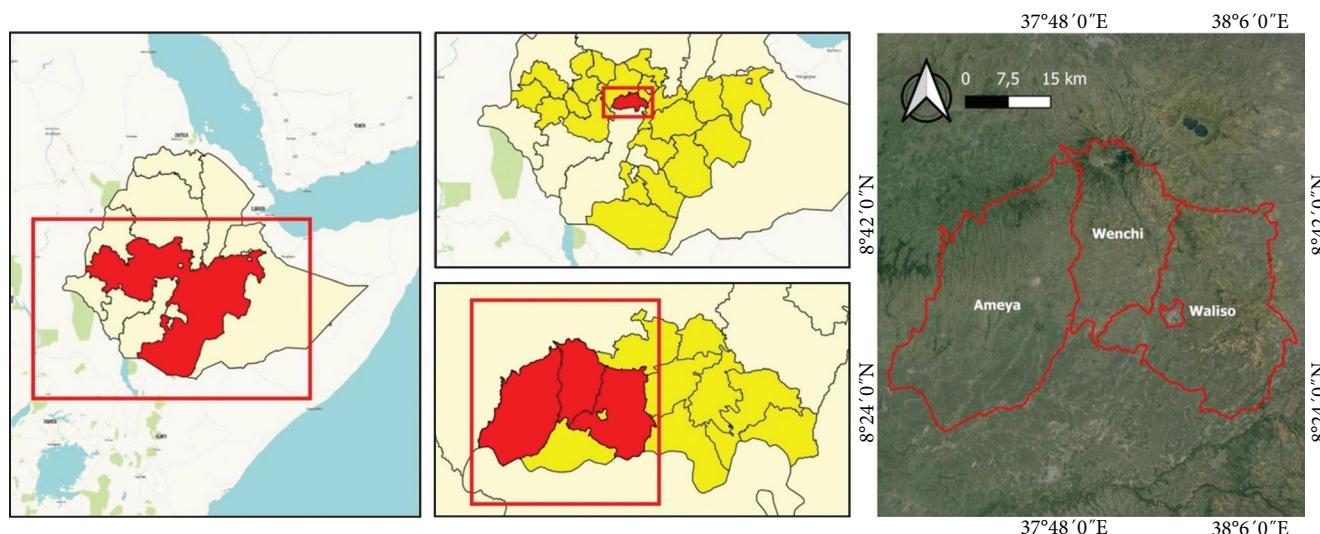


FIGURE 1: Map of the study area.



FIGURE 2: (a and b) Modern bee hive fitted with pollen trap and (c) sorted pollen into homogenous color.

for honey production. Notably, *Erica arborea* honey, a distinctive variety, is produced in the area around Wonchi lake [17].

For optimal exploitation of the zone's substantial beekeeping potential, identifying, documenting, and creating a flowering calendar is essential. Enhancing honey production can be achieved through seasonal colony management aligned with flowering calendars. These practices include timing for feeding, reducing, adding queen excluders, transferring, and harvesting honey, all synchronized with the blooming periods of bee plants. Therefore, the study primarily aimed to identify significant bee forage plants, develop a flowering calendar, and identify the local monofloral honey types across the three districts in the zone.

2. Materials and Methods

2.1. Description of the Study Area. The research took place in the southwest Shoa zone, Oromia region, Ethiopia (Figure 1). Three districts were included in the study—Waliso, Amaya, and Wonchi. Within each district, three specific sites were chosen based on their respective agroecologies. These districts encompass diverse geographic features, including highlands,

midlands, and lowlands. They are also characterized by a variety of natural vegetation and cultivated crops, including horticultural produce suitable for beekeeping, oilseeds, grains, and legumes.

2.2. Data Collection

2.2.1. Establishing Colonies and Gathering Pollen Loads. After standardizing all honeybee colonies, a randomized sampling approach was employed to allocate colonies for honey and pollen collection. A total of 36 honeybee (*Apis mellifera* L.) colonies were established across nine locations spanning three districts within the southwest zone. Each site hosted two colonies dedicated to honey production and two for pollen collection. Additionally, honey samples were gathered from beekeepers. Twelve colonies (six for pollen collection (Figure 2(a)) and six for honey production) were utilized per district. Increasing the number of honeybee colonies did not yield significant additional insights due to consistent floral resources in similar locations. The types of honey and pollen vary seasonally across different agroecologies, influenced by varying flowering plants. A pollen trap with 16%

effectiveness was installed at each colony entrance. The pollen trap was designed to collect the pollen pellets from the hind legs of foraging bees without causing them harm. The trap was checked to ensure that it was functional and correctly positioned to collect sufficient pollen loads over the desired period. Pollen loads were collected every 5 days and stored at hive temperature until analysis (Figure 2(b)). Pollen loads were categorized by color (Figure 2(c)). A small quantity of the collected pollen loads was placed in a clean slide. A few drops of 70% ethanol were added to facilitate homogenization and prevent clumping. The pollen was gently mixed with a sterile spatula. A small amount of the homogenized pollen mixture was then transferred onto a microscope slide. A drop of distilled water was added to the pollen on the slide, and the pollen pellets were gently teased apart with a fine needle or dissecting probe. A drop of glycerin jelly was added to mount the pollen grains, preserving them and providing a clear background for observation. Finally, a coverslip was carefully placed over the mounted pollen, ensuring that no air bubbles were trapped by gently lowering the coverslip at an angle.

2.2.2. Honey Pollen Analysis. A total of 36 honey samples were collected during the honey harvesting seasons for pollen analysis. Each honey type was represented by three samples taken from established honeybee colonies. Each sample weighed ~500 g and was stored at a temperature of 4°C for further examination. Pollen slides were prepared according to the procedures described by Louveaux et al. [18] to analyze the botanical composition and frequency of pollen grains present in the honey.

Ten grams of each honey sample was dissolved in 20 ml of warm water (40°C). The mixture was centrifuged for 10 min at 2,500 rpm (to separate the pollen sediment), after which the clear liquid (supernatant) was carefully poured off, and the remaining sediments were collected into a conical tube for examination [19]. The sediments were then rinsed three times with distilled water to facilitate further pollen extraction from the honey, followed by another round of centrifugation for 5 min at 2,500 rpm. These sediments were then preserved for analysis. Glycerin jelly was used for mounting. To examine the pollen content of the honey samples, three microscope slides were prepared from each sample.

The analysis involved counting at least 500 pollen grains from each sample, following the method outlined by Oliveira et al. [20]. The percentage frequency of pollen types across all samples was computed, excluding pollen from plants observed during the analysis. Pollen types were categorized into four frequency classes based on their contribution to nectar sources—predominant pollen types (>45% of the total pollen grains counted), secondary pollen types (16%–45%), important minor pollen types (3%–15%), and minor pollen types (<3%) [18]. Honeys, where a single pollen type was predominant were classified as monofloral.

2.2.3. Pollen Grains. To analyze the pollen grains, pollen grains were carefully collected from the anthers of flowers and kept in individual envelopes to avoid contamination. For light microscopic preparations, ripe pollen grains were shaken

directly onto microscope slides. To enhance the transparency of the pollen grains, the fat content was washed out using ether to improve the clearness of the pollen grains, ensuring that any large and visible foreign particles were removed before adding glycerin. The slides were then covered with cover slips using warm glycerin jelly. The cover slips were gently pressed together to get a uniform and thin layer of glycerin jelly. Finally, the cover slips were sealed with clear nail varnish. Finally, photo of the pollen archived and used for honey source identification.

2.2.4. Inventory of Bee Forage Plants. Inventorying bee forages began with a thorough 2-year survey and observation of nearby flora to assess their attractiveness to honeybees for nectar and pollen collection. Pollen traps were strategically positioned at the same location year-round, complemented by honey pollen analysis for validation. Following this preliminary phase, a comprehensive plant inventory was undertaken to catalog the bee-attracting plant species in the vicinity.

Transect lines extending north, south, west, and east within a 2 km radius (2 km is economic flight range of honey bees) from apiary sites were established using GPS compasses to ensure directional accuracy. This survey aimed to assess both the quantity and diversity of available bee forage. Apiary sites were strategically spaced within a maximum radius of 6 km to avoid competition and resource overlap.

Within each transect, 20 m × 20 m plots were demarcated at 400 m intervals, as illustrated in Figure 3. Each large plot was subdivided into five 2 m × 2 m (4 m²) subplots to facilitate meticulous counting of grasses and herbaceous species. The identification of all bee forage plant species within each sample plot was meticulously conducted. For plants challenging to identify in the field, standard herbarium methods were employed to collect specimen samples, which were later identified at Holeta Bee Research and the National Herbarium of Addis Ababa University.

2.2.5. Data Analysis. Descriptive statistics were employed for data analysis. Principal component analysis (PCA) was utilized to categorize monofloral honey using the R software. The diversity of bee plants was assessed using the Shannon–Wiener index.

$$\text{Shannon index } (H') = - \sum_{i=1}^s P_i \ln P_i, \quad (1)$$

where H' , Shannon–Wiener diversity index; s , the number of species; P_i , the proportion of individuals or the abundance of the i^{th} species; $\ln$, the natural logarithm; and Σ is the sum from species 1 to species S [21, 22].

The evenness of the species was calculated based on the following formula:

$$J = H' / H_{\max}, \quad (2)$$

where H' is the Shannon–Wiener diversity index, $H_{\max}$ is the maximum value of Shannon–Wiener diversity index, and J is

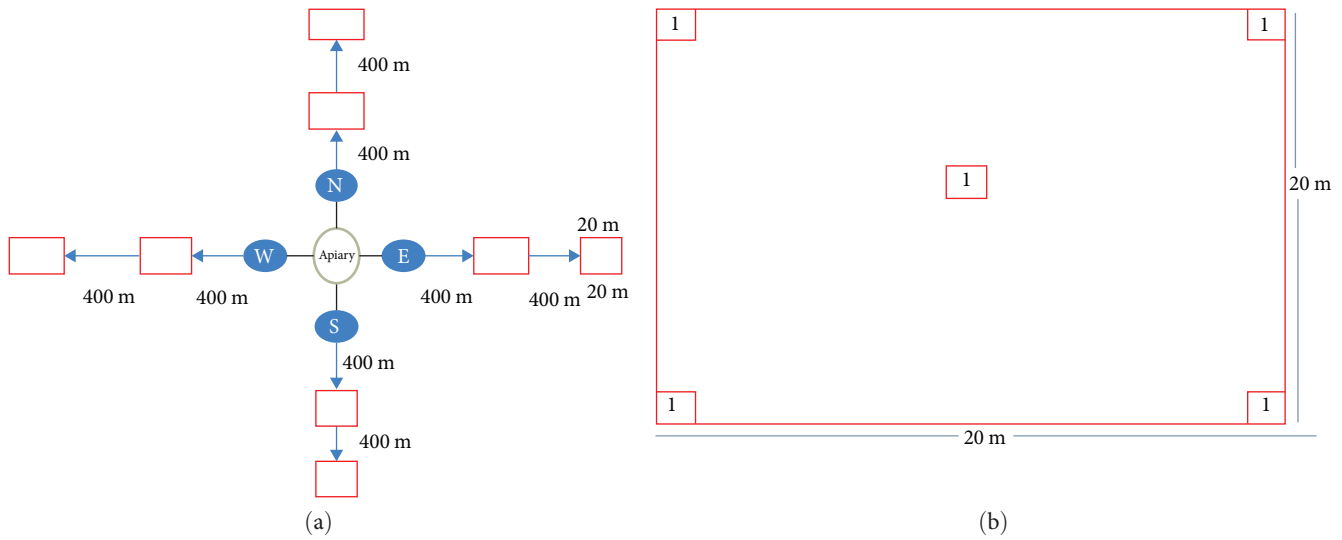


FIGURE 3: (a) Lay out of bee plant inventory and (b) main plot and subplot.

the evenness, the value of J ranges from 0 to 1. Higher values indicate higher levels of evenness. At maximum evenness, $J = 1$.

The relative abundance of bee flora was calculated as the following:

Abundance (A): number of respective tree species divided by extent of sampling area.

Relative abundance (RA): abundance of respective plant species divided by total abundance of all plant species and times 100.

3. Results and Discussions

3.1. Identified Bee Forage Plants and Their Abundance. In a recent field inventory across Waliso, Amaya, and Wonchi districts, a total of 122 plant species were identified as significant bee foraging sources (Table 1). Notably, *Guizotia scabra* (12.08%), *Eucalyptus camaldulensis* (10.06%), and *Vernonia auriculifera* (9.33%) were the most abundant bee forage plants in Waliso district. Meanwhile, *Euclea schimperi* (18.09%) and *E. camaldulensis* (15.49%) dominated in Amaya district. In Wonchi district, *V. auriculifera* (8.77%), *Rumex nervosus* (6%), *E. camaldulensis* (5.44%), *G. scabra* (4.5%), and *E. arborea* (4.32%; Figure 4) were identified as dominant bee forage species.

Across the three districts, 46 plant species (37.40% of the total) were found common, including *Acacia abyssinica*, *Achyranthes aspera*, *Agave sisalana*, *Bersama abyssinica*, *Coffea arabica*, *Cordia africana*, and *Croton macrostachyus*, indicating a broader ecological distribution compared to other species in the area.

Shrubs (44.26%) and trees (27.87%) were the most prevalent life forms among the identified plants, while climbers (7.38%) were the least prevalent (Table 1). This distribution contrasts with findings from the Boda dry evergreen Montane Forest in West Showa, Ethiopia, where trees constituted 34.7%; shrubs, 45.2%; and various other forms made up the remainder [23]. In southwestern Ethiopia, another study

showed that honeybees relied on herbs (36.6%), shrubs (25.8%), trees (23.6%), and climbers (14%) for their primary food sources [24]. These differences highlight how the composition of bee plant species varies across locations based on ecological conditions and vegetation disturbance.

The study underscores that vegetation diversity can vary significantly; high diversity occurs when numerous species are evenly distributed, whereas low diversity results from few species with uneven distribution [25].

3.2. Diversity of Bee Flora Resources in the Study Districts. The highest species diversity ($H' = 4.70$) and species richness (92) were recorded in Wonchi district, with Waliso district following closely (Table 2). However, Waliso district exhibited the greatest Shannon evenness (E). Generally, species richness and diversity tend to be higher in conserved natural forests compared to deforested areas because undisturbed environments allow plant species to regenerate naturally. For instance, Wonchi district, which encompasses the natural forest surrounding Wonchi Crater lake, boasts higher species diversity and richness than other districts. This lake is situated at altitudes ranging from 2,800 to 3,200 m above sea level. Furthermore, the study areas spanned altitudes from 2,200 to 3,200 m above sea level, highlighting the district's varied agroecology. High plant diversity indicates a robust ecosystem capable of withstanding unforeseen environmental changes.

The results of the current study align with previous research, which has demonstrated that species richness and diversity vary with altitude, peaking at intermediate altitudes and decreasing at both lower and higher elevations [26]. Amaya district, predominantly used for agriculture, exhibited lower bee plant species diversity, richness, and evenness than the other districts. A comparable study in the protected landscape of the Philippines reported the highest species diversity at $H' = 3.77$ [27], which is lower than that found in our study area. Plant diversity is influenced by topographic variables such as slopes, aspects, and altitude [28].

TABLE 1: Percent of relative abundance of major bee forage plants in study districts.

Botanical name	Local name	Native/exotic	Habit	Waliso (%)	Amaya (%)	Wonchi (%)
<i>Acacia abyssinica</i> Hochst. ex Benth.	Lafto	Native	Tree	0.63	0.59	0.6
<i>Acacia albida</i> Delile	Garbi	Native	Tree	0	0.34	0
<i>Acacia decurrens</i> Willd.	Kacha	Exotic	Tree	0	0	0.05
<i>Acacia lahai</i> Steud. and Hochst. ex Benth.	Burkukke	Native	Tree	0	0.37	0
<i>Acacia seyal</i> Delile	Wachu	Native	Tree	0.36	1.64	0
<i>Acacia tortilis</i> (Forssk.) Hayne	Taddacha	Native	Tree	0.18	0.43	0
<i>Acanthus sennii</i> Chiov.	Sokorru	Native	Shrub	0.73	0	0.52
<i>Achyranthes aspera</i> L.	Dergu	Native	Herb	0.12	0.07	0.04
<i>Acokanthera schimperi</i> (A.DC.) Schweinf.	Kararu	Native	Shrub	0.11	0.54	0
<i>Agave sisalana</i> Perrine	Alge	Exotic	Shrub	1.53	1.02	0.79
<i>Albizia gummifera</i> (J.F.Gmel.) C.A.Sm.	Mukarba	Native	Tree	0.78	0.69	0.81
<i>Aloe debrana</i> Christian	Argisa	Native	Herb	0	0.04	0
<i>Annona squamosa</i> L.	Gishta	Exotic	Shrub	0	0.01	0
<i>Apodytes dimidata</i> E.Mey. ex Arn.	Chalalaka	Native	Tree	0	0	0.11
<i>Asparagus africanus</i> Lam.	Hidda Sariti	Native	Climber	0.28	0.11	0.16
<i>Bersama abyssinica</i> Fresen.	Lolchisa	Native	Tree	0.63	1.03	1.89
<i>Blepharis edulis</i> (Forssk.) Pers.	Dinnicha sare	Native	Herb	0.24	0.03	0
<i>Brucea antidysenterica</i> J.F.Mill.	Komagno	Native	Tree	0.95	0.04	1.8
<i>Buddleja polystachya</i> Fresen.	Anfara	Native	Shrub	1.50	0	0.36
<i>Caesalpinia decapetala</i> (Roth) Alston	Harangama	Exotic	Climber	2.07	0.289	1.5
<i>Callistemon citrinus</i> (Curtis) Skeels	bottle brush	Exotic	Tree	0.06	0	0
<i>Calpurnia aurea</i> (Aiton) Benth.	Cheka	Native	Shrub	0.34	4.88	1.44
<i>Capparis tomentosa</i> Lam.	Harangama gurracha	Native	Shrub	0.48	0.32	0
<i>Carica papaya</i> L.	Papaya	Exotic	Shrub	0.01	0.30	0
<i>Carissa edulis</i> (Forssk.) Vahl	Agamsa	Native	Shrub	2.33	2.27	2.61
<i>Casimiroa edulis</i> La Llave and Lex.	Casmir	Exotic	Tree	0.01	0.07	0
<i>Catha edulis</i> Forssk.	Chat	Native	Shrub	1.21	1.51	0
<i>Caylusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey.	Riga jarti/Renchi	Native	Herb	1.21	0	0
<i>Citrus sinensis</i> (Mill.) Pers., 1806	Burtukana	Exotic	Shrub	0	0.05	0.02
<i>Clausena anisate</i> (Willd.) Hook.fil.	Ulumaya	Native	Shrub	0.82	0.96	0.61
<i>Clematis simensis</i> Fresen.	Hidda fiti	Native	Climber	1.12	0.04	0.72
<i>Coffea arabica</i> L.	Buna	Native	Shrub	0.85	3.10	0.69
<i>Cordia africana</i> Lam.	Waddessa	Native	Tree	0.52	1.72	0.22
<i>Croton macrostachyus</i> Hochst. ex Delile	Bakannisa	Native	Tree	2.72	2.47	4.46
<i>Cucurbita pepo</i> L.	Bukke	Exotic	Climber	0	0.14	0
<i>Cytisus proliferus</i> L.f.	Treelucern	Exotic	Shrub	0.09	0	0
<i>Datura arborea</i> L.	Turumba	Exotic	Shrub	0.36	0	0.28
<i>Diospyros abyssinica</i> (Hiern) F.White	Diospyros	Native	Shrub	0	0	0.13
<i>Discopodium penninervium</i> Hochst.	Congi	Native	Shrub	0.01	0	0.71
<i>Dodonaea angustifolia</i> Thunb., 1794	Itacha	Native	Tree	0.10	0.16	0.15
<i>Dombeya torrida</i> (J.F.Gmel.) Bamps	Dannisa	Native	Tree	0	0	0.01
<i>Dovyalis caffra</i> (Hook.fil. and Harv.) Warb.	Koshommi	Exotic	Shrub	3.41	1.42	1.7
<i>Erica arborea</i> L.	Kamatte/Sato	Native	Shrub	0	0	4.32
<i>Echinops macrochaetus</i> Fresen.	Korre harre	Exotic	Herb	1.74	0.12	0.12
<i>Ehretia cymose</i> Thonn.	Ulaga	Native	Tree	0	0.06	0
<i>Ekebergia capensis</i> Sparrm.	Sombo	Native	Tree	0.05	0.03	0.02
<i>Embelia schimperi</i> Vatke	Hanku	Native	Shrub	0	0	0.08
<i>Ensete ventricosum</i> (Welw.) Cheesman	Enset	Native	Herb	0.10	0	0.41
<i>Erythrina brucei</i> Schweinf.	Walensu	Native	Tree	0	0.47	0.15
<i>Eucalyptus camaldulensis</i> Denham	Barzafi dima	Exotic	Tree	10.06	15.49	5.44
<i>Eucalyptus globulus</i> Labill.	Barzafi adi	Exotic	Tree	0	0	4.22
<i>Euphorbia tirucalli</i> L.	Hidda Anno	Exotic	Shrub	0	0	0.5

TABLE 1: Continued.

Botanical name	Local name	Native/exotic	Habit	Waliso (%)	Amaya (%)	Wonchi (%)
<i>Flaveria trinervia</i> (Spreng.) C.Mohr	<i>Gororsa</i>	Exotic	Herb	0.24	0	0
<i>Galiniera saxifraga</i> (Hochst.) Bridson	<i>Galiniera</i>	Native	Shrub	0	0	0.11
<i>Galinsoga quadriradiata</i> Ruiz and Pav.	<i>Abbadabbo/kasa</i>	Exotic	Herb	0.60	0	0
<i>Gnidia glauca</i> (Fresen.) Gilg	<i>Didiksa</i>	Native	Shrub	0	0	0.15
<i>Grevillea robusta</i> A.Cunn. ex R.Br.	<i>Grevillea</i>	Exotic	Tree	1.81	0.01	0.49
<i>Grewia ferruginea</i> Hochst.	<i>Dokonu</i>	Native	Tree	1.04	1	0.3
<i>Guizotia scabra</i> (Vis.) Chiov.	<i>Hada/Tufo</i>	Native	Herb	12.08	2.1	4.5
<i>Hagenia abyssinica</i> (Bruce) J.F.Gmel.	<i>Heto</i>	Native	Tree	0.24	0	0.86
<i>Hypericum revolutum</i> Vahl	<i>Garamba/Inne</i>	Native	Tree	0	0	0.18
<i>Hypoestes forskalii</i> (Vahl) R.Br.	<i>Dergu</i>	Exotic	Herb	2.42	0	0
<i>Euclea schimperi</i> (A.DC.) Dandy	<i>Miessa</i>	Native	Shrub	3.09	18.09	0.8
<i>Ipomoea</i> spp.	<i>Hidda kalala</i>	Exotic	Climber	0	0	0.33
<i>Jasminum abyssinicum</i> Hochst. ex DC.	<i>Hidda kamatte</i>	Native	Climber	0.08	0	0
<i>Justicia schimperiana</i> (Hochst. ex Nees) T.Anderson	<i>Dhumuga</i>	Native	Shrub	6.45	4.03	3.8
<i>Kalanchoe deficiens</i> (Forskål) Asch. and Schweinf.	<i>Gommona Osole</i>	Native	Herb	0.41	0.29	0.11
<i>Laggera pterdonata</i> (DC.) Sch.Bip. ex Oliv.	<i>Kaskasse</i>	Native	Herb	0.06	0.16	0.51
<i>Leucas martinicensis</i> (Jacq.) R.Br.	<i>Bokollu</i>	Native	Herb	0	0	1.08
<i>Lippia adoensis</i> Hochst.	<i>Kusaye</i>	Native	Herb	2.42	0.19	1.41
<i>Maesa lanceolata</i> Forssk.	<i>Abayyi</i>	Native	Shrub	0.12	0	0.29
<i>Malus sylvestris</i> Mill.	<i>Apple</i>	Exotic	Shrub	0	0	0.15
<i>Malva verticillata</i> L.	<i>Litti</i>	Exotic	Herb	0.24	0	0.07
<i>Mangifera indicum</i> L.	<i>Mango</i>	Exotic	Tree	0.06	0.78	0.05
<i>Maytenus arbutifolia</i> (Hochst. ex A.Rich.) R.Wilczek	<i>Kartamme</i>	Native	Shrub	2.34	1.88	2.44
<i>Maytenus obscura</i> (A.Rich.) Cufod.	<i>Kombolcha</i>	Native	Tree	0.08	0.07	0
<i>Morus alba</i> L.	<i>Enjorri</i>	Exotic	Shrub	0	0.01	0
<i>Musa paradisiaca</i> L.	<i>Muz</i>	Exotic	Herb	0.04	0.05	0.05
<i>Myrsine africana</i> L.	<i>Kachama</i>	Native	Shrub	0	0	1.28
<i>Ocimum lamiifolium</i> Hochst. ex Benth.	<i>Wanchabbi</i>	Native	Shrub	0.45	1.18	0.14
<i>Ocimum urticifolium</i> L.	<i>Damakase</i>	Native	Shrub	2.03	0.43	0.69
<i>Ocotea kenyensis</i> (Chiov.) Robyns and R.Wilczek	<i>Buniti</i>	Native	Shrub	0.17	0.19	0.55
<i>Olea europaea</i> L.	<i>Ejersa</i>	Native	Tree	0.36	0.12	1.03
<i>Olinia rochitina</i> A.Juss.	<i>sole</i>	Native	Tree	0.01	0	2.56
<i>Opuntia ficus-indica</i> (L.) Mill.	<i>Adammi</i>	Exotic	Shrub	0.01	0	0.01
<i>Osyris quadripartite</i> Salzm. ex Decne.	<i>Wato</i>	Native	Shrub	0.28	0.52	1.4
<i>Otostegia integrifolia</i> Benth.	<i>Tunjiti</i>	Native	Shrub	0	0	0.04
<i>Pavonia urens</i> Cav.	<i>Inchinni</i>	Native	Shrub	0.35	0	0.14
<i>Periploca linearifolia</i> Dillon and A.Rich.	<i>Hidda Ananno</i>	Native	Climber	0	0.78	2.63
<i>Persea americana</i> Mill.	<i>Avocado</i>	Exotic	Tree	0.38	0.45	0.12
<i>Phoenix reclinata</i> Jacq.	<i>Meti</i>	Exotic	Tree	0.39	0	0
<i>Phytolacca dodocandra</i> L'Hér.	<i>Andode</i>	Native	Shrub	0.4	0.11	0.34
<i>Plantago lanceolata</i> L.	<i>Kortobbi</i>	Exotic	Herb	1.33	0	0
<i>Premna schimperi</i> Engl.	<i>Urgessa</i>	Native	Shrub	0.58	0.19	0.14
<i>Rhamnus prinoides</i> L'Hér.	<i>Gesho</i>	Native	Shrub	1.06	0.11	0.14
<i>Rhus glutinosa</i> Hochst. ex A.Rich.	<i>Tatessa</i>	Native	Tree	0.28	0.58	0.29
<i>Ricinus communis</i> L.	<i>Kobbo</i>	Native	Shrub	0.79	0.45	0.13
<i>Rosa abyssinica</i> R.Br.	<i>Gora</i>	Native	Shrub	0	0.55	0.73
<i>Rubus steudneri</i> Schweinf.	<i>Altufa</i>	Native	Shrub	0	0.27	0.15
<i>Rumex nervosus</i> Vahl	<i>Dhangaggo</i>	Native	Shrub	0.24	0	6
<i>Ruta chalepensis</i> L.	<i>Teneddam</i>	Exotic	Herb	0.12	0	0
<i>Salix subserata</i> Willd.	<i>Alaltu</i>	Native	Shrub	0.08	0.26	0.07

TABLE 1: Continued.

Botanical name	Local name	Native/exotic	Habit	Waliso (%)	Amaya (%)	Wonchi (%)
<i>Salvia leucantha</i> Cav.	<i>Salvia</i>	Exotic	Herb	0.12	0	0
<i>Satureja paradoxa</i> (Vatke) Engl. ex Seybold	<i>Tosign</i>	Native	Herb	0	0	0.33
<i>Schinus mole</i> L.	<i>Kundebarebare</i>	Exotic	Shrub	0.12	0	0
<i>Sesbania sesban</i> (L.) Merr.	<i>Sasbania</i>	Exotic	Shrub	0.71	0	0.06
<i>Sesamum indicum</i> L.	<i>Salit</i>	Exotic	Herb	0	0	0.16
<i>Solanecio gigas</i> (Vatke) C.Jeffrey	<i>Bosokke</i>	Native	Shrub	0	0	0.18
<i>Solanum stramonium</i> L.	<i>Manji</i>	Native	Herb	0	0.19	0.04
<i>Solanum incanum</i> L.	<i>Hiddi loni</i>	Native	Shrub	1.81	2.47	2.54
<i>Syzygium guineense</i> (Willd.) DC.	<i>Badessa</i>	Native	Tree	0.03	0	0.04
<i>Tagetes minuta</i> L.	<i>Ajo</i>	Exotic	Herb	0	0	0.28
<i>Trifolium ruppellianum</i> Fresen.	<i>Sidisa</i>	Native	Herb	3.62	0	1.99
<i>Urera hypselodendron</i> (Hochst. ex A.Rich.) Wedd.	<i>Lanqisa</i>	Native	Climber	0.06	0	0.27
<i>Urtica simensis</i> Hochst. ex A.Rich.	<i>Dobbi</i>	Native	Herb	0	0	3.11
<i>Vepris dainellii</i> (Pic.Serm.) Kokwaro	<i>Hadhessa</i>	Native	Shrub	0.17	0.29	0
<i>Verbascum sinaiticum</i> Benth.	<i>Gurra Harre</i>	Exotic	Herb	0	0	0.08
<i>Vernonia adoensis</i> Sch.Bip. ex Walp.	<i>Sukke</i>	Native	Shrub	0	0.03	0.22
<i>Vernonia amygdalina</i> Delile	<i>Ebicha</i>	Native	Shrub	1.45	0.69	1.7
<i>Vernonia auriculifera</i> Hiern	<i>Reji</i>	Native	Shrub	9.33	6.5	8.77
<i>Vernonia hochstetteri</i> Sch.Bip. ex Walp.	<i>Damot gurra</i>	Native	Shrub	1.39	0	1.3
<i>Zehneria scabra</i> (L.fil.) Sond.	<i>Hidda Kattisa</i>	Native	Climber	0.22	0.44	0.44

FIGURE 4: *Erica arborea* and its flowers around Wonchi Creator lake in southwest Shoa, Ethiopia. (These pictures were taken during plant inventory around the lake).

TABLE 2: Diversity indices of the bee flora resources for Waliso, Wonchi and Amaya districts in southwest Shoa, Ethiopia.

District	Species richness	Shannon's diversity index (H')	Shannon evenness (E)
Waliso	86	4.55	0.59
Wonchi	92	4.70	0.58
Amaya	71	4.08	0.53

The biodiversity value of any area is typically assessed in terms of species richness [27].

3.3. Flowering Period of Major Bee Forages in Waliso, Amaya, and Wonchi Districts. Bee plant species have varying flowering times, depending on the duration of the rainy season. For instance, bee forage plants that bloom from September to November are expected to yield honey by late November or early December. Honey harvested around this time is

derived from plants such as *G. scabra*, *H. forskoolii*, *Bidens* species, *Trifolium* species, and *C. africana* (Table 3). Conversely, bee forage plants that flower from April to May produce honey by late May or as late as mid-June, again depending on the rainy season's timing. For instance, in June, honey is produced by *C. macrostachyus* and some *Eucalyptus* species (Table 3). A study conducted in Gera, southwestern Ethiopia, found that 81% of bee plants flowered between September and November, 10.8% between

TABLE 3: Flowering period of major bee forage plant species in Waliso, Amaya, and Wonchi districts.

Plant species	S	O	N	D	Jan	F	Mr	Ap	My	Jun	Jul	Au
<i>Hypoestes forskalii</i> (Vahl) R.Br.	—	■	■	—	—	—	—	—	—	—	—	—
<i>Acacia</i> spp.	—	—	—	—	—	—	■	■	—	—	—	—
<i>Bersama abyssinica</i> Fresen.	—	—	■	■	—	—	—	—	—	—	—	—
<i>Bidens</i> spp.	■	■	—	—	—	—	—	—	—	—	—	—
<i>Croton macrostachyus</i> Hochst. ex Delile	—	—	—	—	—	—	—	—	■	■	—	—
<i>Clematis hirsute</i> Guill. and Perr.	—	—	■	■	—	—	—	—	—	—	—	—
<i>Echinops macrochaetus</i> Fresen.	—	—	■	■	—	—	—	—	—	—	—	—
<i>Eucalyptus camaldulensis</i> Denham	—	—	■	—	—	—	■	■	—	—	—	—
<i>Erica arborea</i> L.	—	■	■	■	—	—	—	—	—	—	—	—
<i>Eucalyptus globulus</i> Labill.	—	—	—	—	—	—	■	■	—	—	—	—
<i>Guizotia scabra</i> (Vis.) Chiov.	—	■	■	—	—	—	—	—	—	—	—	—
<i>Vernonia auriculata</i> Hiern	—	—	—	■	■	—	—	—	—	—	—	—
<i>Vernonia amygdalina</i> Delile	—	—	—	■	■	—	—	—	—	—	—	—
<i>Pavonia urens</i> Cav.	■	■	■	—	—	—	—	—	—	—	—	—
<i>Plantago lanceolata</i> L.	—	—	■	■	—	—	—	—	—	—	—	—
<i>Rumex nervosus</i> Vahl	—	—	■	■	—	—	—	—	—	—	—	—
<i>Syzygium guineense</i> (Willd.) DC.	—	—	—	—	—	■	■	—	—	—	—	—
<i>Trifolium</i> spp.	■	■	—	—	—	—	—	—	—	—	—	—
<i>Cordia Africana</i> Lam.	■	■	—	—	—	—	—	—	—	—	—	—
<i>Vicia faba</i> L.	—	—	■	■	—	—	—	—	—	—	—	—

Note. S, September; O, October; N, November; D, December; Jan, January; F, February; Mr, March; Ap, April; My, May; Jun, June; Jul, July; and Au, August.

March and May, and a small percentage between December and February [5].

3.4. Pollen Load Analysis. Based on the analysis of pollen loads, 31 significant pollen source plants were identified. Among these, *Bidens prestinaria*, *E. camaldulensis*, *E. globulus*, *G. scabra*, *P. lanceolata*, *Mesaea lanceolata*, *Trifolium species*, and *Vernonia species* were most frequently visited by honeybees for pollen, with visits spanning over 50 days. Plants such as *E. macrochaetus*, *Maytenus obscura*, *V. faba*, *Apodytes dimidiata*, *C. abyssinica*, *H. abyssinica*, and *Terminalia schimperiana* were moderately visited for pollen for 30–45 days. The remaining species were seldom visited by honeybees, with visits lasting less than 30 days (Table 4).

Pollen is not only essential for plant pollination and fertilization, but it is also vital for the development and growth of honeybee colonies [29]. Our study's detection of pollen loads using pollen traps offers insights into honeybee preferences and the abundance of resources since honeybees are primary pollen collectors. This research demonstrates that honeybees gather pollen from a diverse range of plant

species, underscoring the relative importance of each plant species as a pollen source for honeybees.

3.5. Seasonal Availability of Pollen. Throughout the year, the fresh weight of pollen collected exhibited considerable variation in peaks; however, significant amounts were consistently gathered in almost all districts during September, October, November, April, and May. These findings align with previous studies that indicate that the seasonal variations in pollen availability are common due to the differing flowering periods of plants [30, 31].

Depending on the rainfall, honey can be harvested at the end of November or the beginning of December and again at the end of May or the beginning of June. This seasonal harvesting schedule is consistent with the work of Thompson and Hunt [32], who found that honey production is closely linked to rainfall patterns and floral abundance.

Conversely, February, March, July, and August exhibited minimal bee foraging activity across all three districts, necessitating supplemental feeding during these months of scarcity. This observation is supported by previous research

TABLE 4: Tentative foraging day of the major bee forages in Waliso, Amaya, and Wonchi districts from trapped pollen.

Plant species	Families	Starting	Ending	Foraging day
<i>Andropogon abyssinica</i> R.Br. ex Fresen.	Poaceae	December	February	25
<i>Apodytes dimidiata</i> E.Mey. ex Arn.	Iciniaceae	January	February	30
<i>Bidens prestinaria</i> (Sch.Bip.) Cufod.	Asteraceae	September	November	70
<i>Brassica carinata</i> A.Braun	Brassicaceae	September	December	20
<i>Caylusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey.	Resedeaceae	October	November	35
<i>Cleome usambarica</i> Pax ex Engl.	Cappriadeae	January	February	28
<i>Crambe abyssinica</i> Hochst. ex R.E.Fr.	Brassicaceae	June	August	20
<i>Cyperus longus</i> L.	Cyperaceae	March	May	20
<i>Datura arborea</i> L.	Solanaceae	May	October	50
<i>Dombeya torrida</i> (J.F.Gmel.) Bamps	Sterculiaceae	September	November	20
<i>Echinops macrochaetus</i> Fresen.	Asteraceae	October	December	45
<i>Erica arborea</i> L.	Ericaceae	October	December	20
<i>Eucalyptus camaldulensis</i> Denham	Myrtaceae	April	June	65
<i>Eucalyptus globulus</i> Labill.	Myrtaceae	April	June	70
<i>Guizotia scabra</i> (Vis.) Chiov.	Asteraceae	October	November	95
<i>Hagenia abyssinica</i> (Bruce) J.F.Gmel.	Roseaceae	October	December	35
<i>Hypoestes triflora</i> (Forssk.) Roem. and Schult.	Acanthaceae	October	December	25
<i>Justicia heterocarpa</i> T.Anderson	Acanthaceae	November	December	25
<i>Maytenus obscura</i> (A.Rich.) Cufod.	Celastraceae	March	May	45
<i>Mesea lanceolata</i> (Merr.) Kosterm.	Myrsinaceae	September	November	50
<i>Ocimum basilicum</i> L.	Lamiaceae	August	November	20
<i>Pavonia urens</i> Cav.	Malvaceae	September	November	25
<i>Plantago lanceolata</i> L.	Plantaginaceae	October	December	115
<i>Rumex nervosus</i> Vahl	Polygonaceae	September	December	87
<i>Sesamum indicum</i> L.	Pedaliaceae	October	November	20
<i>Schinus molle</i> L.	Anacardiaceae	September	October	20
<i>Syzygium guineense</i> (Willd.) DC.	Myrtaceae	January	March	20
<i>Terminalia schimperiana</i> Hochst. ex Engl. and Diels	Combretaceae	October	November	30
<i>Trifolium</i> spp.	Fabaceae	September	December	59
<i>Vernonia amygdalina</i> Delile	Asteraceae	December	February	57
<i>Vicia faba</i> L.	Fabaceae	August	September	45

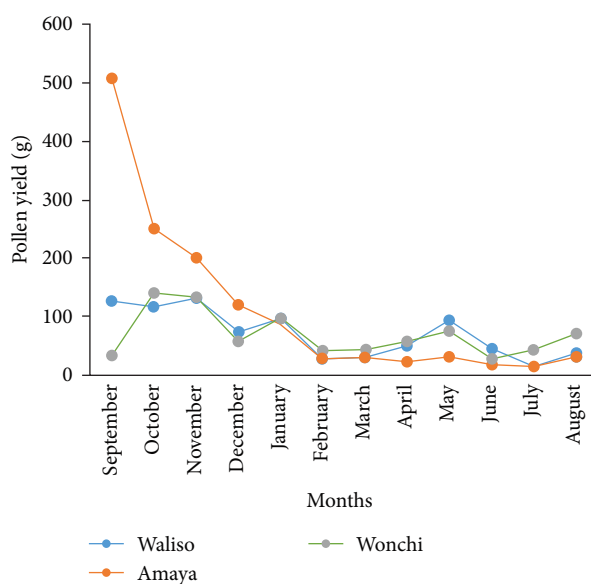


FIGURE 5: Monthly pollen gathered from Waliso, Amaya, and Wonchi districts.

TABLE 5: Bee forage plants that contributed for honey produced in November, January, and June from Waliso, Amaya, and Wonchi districts.

Plant species	Local name (A/Oromo)	Family	Life form	Honey harvesting period	Amaya	Waliso	Wonchi
<i>Acacia abyssinica</i> Hochst. ex Benth.	<i>Lafto</i>	Fabaceae	Tree	November	+	+	+
<i>Acacia albidia</i> Delile	<i>Garbi</i>	Fabaceae	Tree	December	+	-	-
<i>Acacia tortilis</i> (Forssk.) Hayne	<i>Taddacha</i>	Fabaceae	Tree	January	+	+	-
<i>Acanthus semii</i> Chiov.	<i>Sokorru</i>	Acanthaceae	Shrub	November	-	+	+
<i>Bersama abyssinica</i> Fresen.	<i>Lolchisa</i>	Melanthaceae	Shrub	November	+	+	+
<i>Bidens prestinaria</i> (Sch.Bip.) Cufod.	<i>Kello</i>	Asteraceae	Herb	November	+	+	+
<i>Brassica carinata</i> A.Braun	<i>Rafu</i>	Brassicaceae	Herb	November	+	+	+
<i>Carissa edulis</i> (Forssk.) Vahl	<i>Agamsa</i>	Celastraceae	Shrub	October	+	+	+
<i>Cayusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey.	<i>Riga jartii/Renchi</i>	Resedaceae	Herb	November	-	+	-
<i>Cordia africana</i> Lam.	<i>Wadessa</i>	Boraginaceae	Tree	November	+	+	+
<i>Croton macrostachyus</i> Hochst. ex Delile	<i>Bakkannisa</i>	Euphorbiaceae	Tree	August	+	+	+
<i>Dombeya torrida</i> (J.F.Gmel.) Bamps	<i>Dannisa</i>	Sterculiaceae	Tree	November	-	-	+
<i>Erica arborea</i> L.	<i>Sato/Kamatte</i>	Ericaceae	Shrub	January	-	-	+
<i>Eucalyptus camaldulensis</i> Denham	<i>Barzafi dima</i>	Myrtaceae	Tree	June	+	+	+
<i>Eucalyptus globulus</i> Labill.	<i>Barzafi adi</i>	Myrtaceae	Tree	June	-	-	+
<i>Guizotia scabra</i> (Vis.) Chiov.	<i>Hada/Tufo</i>	Asteraceae	Herb	November	+	+	+
<i>Hagenia abyssinica</i> (Bruce) J.F.Gmel.	<i>Heto</i>	Rosaceae	Tree	January	-	+	+
<i>Hypoestes forskoalii</i> (Vahl) R.Br.	<i>Dergu</i>	Acanthaceae	Herb	November	-	+	-
<i>Maytenus trifloral</i> (Forssk.) Roem. and Schult.	<i>Dergu</i>	Acanthaceae	Herb	November	+	+	+
<i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell	<i>Kartamme</i>	Celastraceae	Shrub	November	+	+	+
<i>Maytenus obscura</i> (A.Rich.) Cufod.	<i>Kombolcha</i>	Celastraceae	Tree	February	+	+	-
<i>Mesaa lanceolata</i> (Merr.) Kosterm.	<i>Abayyi</i>	Myrsinaceae	Shrub	November	-	+	+
<i>Ocimum basilicum</i> L.	<i>Damakase</i>	Lamiaceae	Shrub	November	+	+	+
<i>Pavonia urens</i> Cav.	<i>Inchimi</i>	Malvaceae	Shrub	November	-	+	+
<i>Rumex nervosus</i> Vahl	<i>Dhanggo</i>	Polygonaceae	Shrub	January	-	+	+
<i>Sesamum indicum</i> L.	<i>Salit</i>	Pedaliaceae	Herb	November	-	-	+
<i>Solanecio gigas</i> (Vatke) C.Jeffrey	<i>Bosokke</i>	Asteraceae	Shrub	January	-	-	+
<i>Syzygium guineense</i> (Willd.) DC.	<i>Baddessa</i>	Myrtaceae	Tree	September	-	+	+
<i>Trifolium</i> spp.	<i>Sidisa</i>	Fabaceae	Herb	November	-	+	+
<i>Vernonia amygdalina</i> Delile	<i>Ebicha</i>	Asteraceae	Shrub	January	+	+	+
<i>Vernonia auriculata</i> Hiern	<i>Rejji</i>	Asteraceae	Shrub	January	+	+	+
<i>Vicia faba</i> L.	<i>Bakela</i>	Fabaceae	Herb	November	+	+	+

Note. "+" for presence and "-" for absence of plant species in each district.

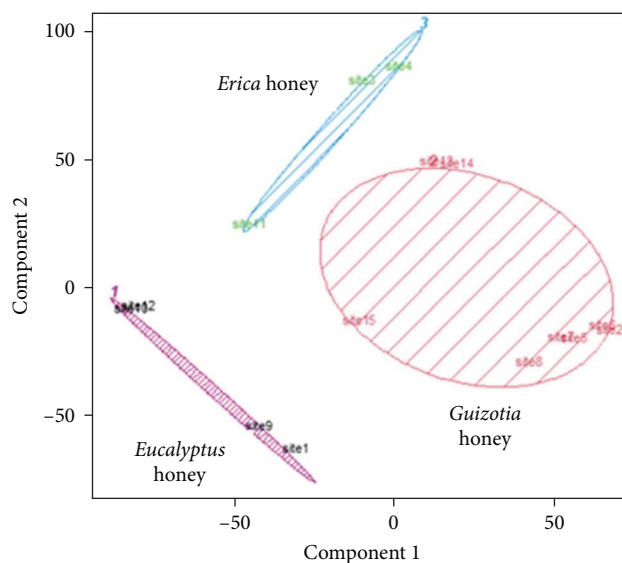


FIGURE 6: Monofloral honey types from southwest Shoa zone.

indicating that supplemental feeding is essential during periods of low floral availability to maintain colony health and productivity [33].

The following graphs (Figure 5) illustrate the periods of highest pollen availability, followed by medium, low, and no pollen at all, across each district in the study areas. These data are utilized to manage honeybee colonies throughout the year, indicating optimal times to add supers, reduce supers, harvest honey, and provide additional food resources. Managing bee colonies based on pollen availability is a well-documented practice, with studies showing that strategic management can significantly enhance colony health and honey production [34, 35].

3.6. Honey Harvesting Calendars. Three honey harvesting periods were identified in the study areas—November, January, and June. Two monofloral honeys, *Eucalyptus* and *Erica*, come from woody plants. Research in southwestern Ethiopia supports this, with 86.7% of monofloral honey from woody plants and only 13.3% from weeds and crops [36].

In Wonchi district, *Erica* honey is the sole type produced, whereas *Guizotia* and *Eucalyptus* honeys are produced in all the districts covered by the study. Different bee forage plants contributed to each monofloral honey during these seasons (Table 5). For November honey production, the majority (50%) of the contributing bee plants were herbaceous (Table 5). Conversely, shrubs played a larger role in the production of January honey (Table 5). The frequency and timing of honey harvesting vary from place to place depending on the types of bee forage plants available. For instance, in Gera, southwestern Ethiopia, honey can be harvested four times a year [5], while in the Guji zone, it can be harvested up to three times annually [7]. In the Borena zone of southern Ethiopia, honey production occurs once or twice a year [11], depending on rainfall availability.

3.7. Honey Pollen Analysis. PCA clustering of pollen percentage counts identified three distinct types of monofloral honey in the study area—*G. scabra*, *E. arborea*, and *E. camaldulensis* (Figure 6). *Guizotia* and *Eucalyptus* honeys dominate regions with extensive cultivation, while *Erica* honey is unique to Haro Wonchi in the Wonchi district.

Honey pollen analysis identified 35 plant species as honey sources (Table 6). Major sources contributing over 45% of total pollen content include *G. scabra*, *E. camaldulensis*, and *E. arborea*, aligning with previous studies on their abundant floral resources and bee attractiveness.

Guizotia species, known for prolific flowering and high nectar yield, are major pollen and nectar sources for honeybees, producing high-quality honey [37]. *Eucalyptus* species are major nectar sources globally due to their adaptability and extended flowering periods [38]. *E. arborea*, significant in Mediterranean and African regions, attracts bees with its extended blooming season and high pollen and nectar yield [39].

Secondary pollen sources (16%–45% pollen count) include *C. macrostachyus*, *B. carinata*, *H. triflora*, and *C. africana*, essential for sustaining honey production and bee health [40].

G. scabra was the main honey source in most study districts in October and November, *Eucalyptus* species in June in Amaya and Waliso districts, and *E. arborea* in December at Haro Wonchi in Wonchi district. In other Wonchi district areas, *G. scabra* was primary, followed by *E. camaldulensis* for June honey production. *G. scabra* monofloral honey is widely produced in Ethiopia's Oromia region, including Borena zone (Abbaya, Dugda Dawwa, and Teltelle districts) and Guji zone (Adola Redde district) [11].

3.8. Microscopic Photograph of Pollens for Some Major Bee Plants. The pollen shape is a crucial factor in identifying the botanical source of honey and honeybee-collected pollen. In the study area, specific pollen shapes corresponding to major

TABLE 6: Predominate and secondary pollen source plants in the study area.

District	Predominant pollen source (>45%)	Secondary pollen (16%–45%)	Important minor pollen (3%–15%)	Minor pollen source (<3%)
Waliso	<i>Guizotia scabra</i> (Vis.) Chiov.	<i>Brassica carinata</i> A.Braun <i>Cordia africana</i> Lam.	<i>Caylusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey. <i>Hypoestes forskoolii</i> (Vahl) R.Br. <i>Maytenus gracilipes</i> (Welw. ex Oliv.) Exell <i>Bidens prestinaria</i> (Sch.Bip.) Cufod.	<i>Bersama abyssinica</i> Fresen. <i>Vicia faba</i> L. <i>Pavonia urens</i> Cav. <i>Eucalyptus camaldulensis</i> Denham <i>Ocimum basilicum</i> L. <i>Hypoestes triflora</i> (Forssk.) Roem. & Schult.
			<i>Syzygium guineense</i> (Willd.) DC. <i>Acacia tortilis</i> (Forssk.) Hayne <i>Maytenus obscura</i> (A.Rich.) Cufod.	<i>Carissa edulis</i> (Forssk.) Vahl
	<i>Eucalyptus camaldulensis</i> Denham	<i>Croton macrostachyus</i> Hochst. ex Delile	<i>Sesamum indicum</i> L.	<i>Hypoestes forskoolii</i> (Vahl) R.Br. <i>Ocimum basilicum</i> L.
	<i>Guizotia scabra</i> (Vis.) Chiov.	<i>Cordia africana</i> Lam.	<i>Caylusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey. <i>Maytenus obscura</i> (A.Rich.) Cufod.	<i>Bidens prestinaria</i> (Sch.Bip.) Cufod. <i>Syzygium guineense</i> (Willd.) DC. <i>Acacia albida</i> Delile
Amaya	<i>Eucalyptus camaldulensis</i> Denham	<i>Croton macrostachyus</i> Hochst. ex Delile	<i>Hagenia abyssinica</i> (Bruce) J.F.Gmel. <i>Rumex nervosus</i> Vahl <i>Solanecio gigas</i> (Vatke) C.Jeffrey <i>Acacia abyssinica</i> Hochst. ex Benth. <i>Eucalyptus globulus</i> Labill.	<i>Bersama abyssinica</i> Fresen. <i>Vernonia auriculata</i> Hiern <i>Vernonia amygdalina</i> Delile <i>Carissa edulis</i> (Forssk.) Vahl <i>Syzygium guineense</i> (Willd.) DC.
	<i>Erica arborea</i> L.	—	<i>Trifolium</i> spp.	<i>Pavonia urens</i> Cav.
	<i>Eucalyptus camaldulensis</i> Denham	<i>Croton macrostachyus</i> Hochst. ex Delile	<i>Caylusea abyssinica</i> (Fresen.) Fisch. and C.A.Mey. <i>Dombeya torrida</i> (J.F.Gmel.) Bamps <i>Brassica carinata</i> A.Braun <i>Ocimum basilicum</i> L.	<i>Hypoestes forskoolii</i> (Vahl) R.Br. <i>Acanthus senii</i> Chiov. <i>Mesaa lanceolata</i> (Merr.) Kosterm.
	<i>Guizotia scarba</i>	<i>Hypoestes triflora</i> (Forssk.) Roem. and Schult.		
Wonchi				

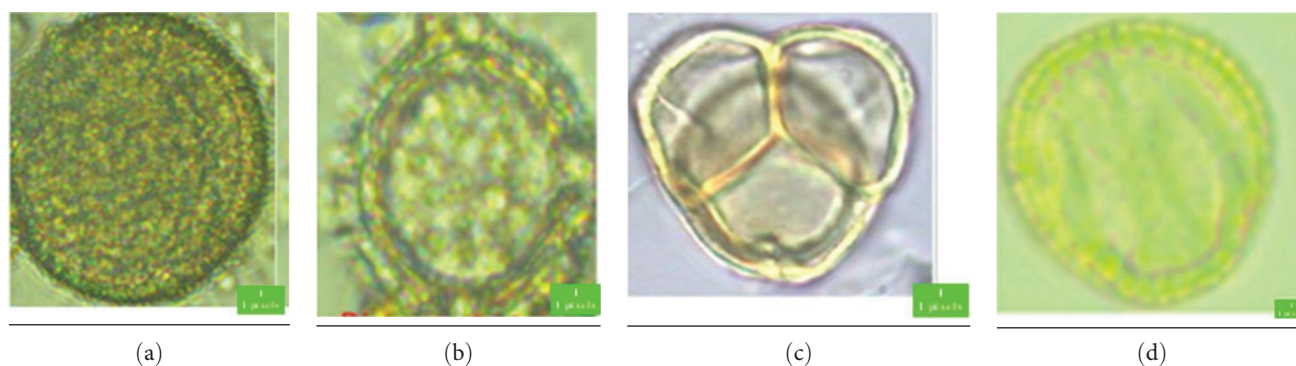


FIGURE 7: Pollen pictures of some major honey flora that are identified in the study area. (a) *C. macrostachyus* Hochst. ex Delile, (b) *V. amygdalina* Delile, (c) *E. arborea* L., and (d) *B. carinata* A.Braun.

bee forage plants were identified, facilitating the determination of the plant species visited by bees. This method of botanical source identification is supported by previous research, which has consistently demonstrated the importance of pollen morphology in melissopalynology (the study of pollen in honey; Figure 7).

A relevant study by Sawyer [41] highlights the significance of pollen shape and size in identifying plant species in honey samples. Sawyer's work established a comprehensive reference for pollen morphology, which has been widely used in subsequent research for identifying botanical sources of honey. Additionally, Jones and Bryant [42] provided a detailed analysis of pollen grains from various plants, emphasizing the distinctive characteristics such as shape, size, and surface texture that aid in accurate identification.

4. Conclusion

The study identified 122 plant species through plant inventory, honey pollen analysis, and pollen load collection. The Wonchi district exhibited the highest diversity of bee forage plants, followed by Waliso. The research also identified three honey harvesting calendars. Three types of monofloral honey are produced in the area—*Guizotia* honey in November, *Erica* honey in January, and *Eucalyptus* honey in June. There is a shortage of bee forage in February, March, July, and August across all districts in the study area, necessitating supplementary feeding during these months. Overall, the available bee flora resources indicate that the southwest Shoa zone (Wonchi, Waliso, and Amaya districts) has significant potential for sustainable and commercial beekeeping. To ensure sustainability, it is crucial to preserve existing bee flora and promote the cultivation of multipurpose plant species. Additionally, increasing awareness through farm demonstrations on the importance of floral and honey calendars is recommended to enhance the management of honeybee colonies and boost honey harvest frequency.

Data Availability

The data that support the findings of the study are available from the corresponding author upon the reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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