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Research article

Bee flora diversity in different vegetation communities of Gesha-Sayilem forest in Kaffa Zone, south-western Ethiopia

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Abstract: Tropical Afromontane forest has the potential for honey production. The main objective of the study was to identify major bee floras and its diversity in different vegetation communities of Gesha-Sayilem forest. Bee flora data were collected systematically from 90 plots with subplots for shrubs and herbaceous species. In addition, pollen traps having 16% pollen trapping efficiency were fitted at the entrance of beehives for pollen load collection. Shannon-Wiener diversity index; species richness and Shannon's evenness were employed to determine diversity of bee flora. The result showed that 93 bee plant species belongings to 43 families were identified of which Asteraceae the most abundant family was followed by Lamiaceae, Fabaceae, Acanthaceae and Rubiaceae. The analysis of bee forage diversity using Shannon-Wiener diversity index (H) found in 5 different plant communities showed that plant communities one, two, and three have the highest bee flora diversity 3.2, 3.2, and 3.5, respectively. The dominant bee plants in community one were (*Ilex mitis* and *Syzygium guineens*), community two (*Pouteria adolfi-friederici* and *Schefflera abyssinica*), Community three (*Millettia ferruginea* and *Sapium ellipticum*), community four (*Hagenia abyssinica* and *Dombeya torrida*), community five (*Schefflera-volkensi* and *Maesa lanceolata*). Sorensen similarity coefficient showed that communities 1, 2, 3, and 5 are more similar to each other while community four is less similar. On the other hand, the beta diversity for communities 1, 2, 3, and 5 were 0.25, 0.27, 0.39, and 0.28 respectively while community four has a higher beta diversity index (0.71) indicating low similarity with the rest of the plant communities. In conclusion community 1, 2 and 3 has a high diversity of bee flora and therefore, integration of these communities with beekeeping is recommended.

Keywords: Plant, Honeybee, Pollen, Dominant, Nectar, Honey.

INTRODUCTION

Ethiopia is one of the world's most plant species-rich countries (Senbeta *et al.*, 2014; Kelbessa & Demissew, 2014; Kassa *et al.*, 2016). As a result, it is an origin of diversity and endemism for several plant species (Husen *et al.*, 2012; Assefa *et al.*, 2014; Tadesse *et al.*, 2017; Yahya *et al.*, 2019). Ethiopia has about 6000 species of higher plants including 647 (10.74%) endemic taxa (Kelbessa & Demissew, 2014; Gebrehiwot & Hundera, 2014). The natural forests of Ethiopia have ecological and economical values (FAO, 2016; Arts & de Koning, 2017; Macqueen *et al.*, 2018; Guta & Telake, 2019). However, it is highly under pressure (Senbeta *et al.*, 2014; Tadesse *et al.*, 2017; Shiferaw *et al.*, 2018). In Ethiopia, the main causes of deforestation are for agricultural expansion, charcoal production, settlements, for fuelwood and construction material (Tura *et al.*, 2017; Yirga *et al.*, 2019). The south-west montane forests are mainly depleted for coffee plantation (Wood *et al.*, 2019).

Beekeeping is one of the most important agricultural activities in many parts of Ethiopia. The diversified agro-climatic conditions of the country create conducive environmental conditions for the growth of thousands of flowering plants of which most are honeybee plants (Bareke & Addi, 2018; Bareke & Addi, 2019a). Annually 54,000 metric tons of honeys are produced in Ethiopia, 24% of the Africa production, representing a value of about 620 million Birr (CSA 2015). The Moist Afromontane Forests of South-west Ethiopia have the potential for beekeeping that would serve as a major source of household income (Bareke & Addi, 2019a). In the Kaffa zone, there is an intact natural forest, a dense honeybee population and huge water resources. Honey production is an important source of income for smallholder farmers in the area. As a result, the large volume of honey is produced annually.

In most parts of the south-west forest of Ethiopia, honey production is the second important agricultural activity next to Ensete (*Ensete ventricosum* (Welw.) Cheesman.) and average of 20-30 beehives are owned by households. Although the yields vary with the rainfall in the area, one hive can produce about 10-15 kg/hive from traditional beehives and 30-52 kg/hive from improved beehives (Getachew *et al.*, 2012). The honey is used both as a source of food and medicine for local communities, as well as a source of revenue.

Beekeepers in the Gesha-Sayilem forest have a better understanding of the value of the forest for honey production. For instance, the traditional beekeepers in the area have long-established traditional forest management practices, which locally called "KOBO". KOBO is a block of forest land bounded and demarcated by big trees and or physical features

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like the river and small streams and exclusively used for the purpose of traditional beekeeping (Addi, 2018). From the forest resource management perspective, forest beekeeping is the most important activity, that connects the farmers' economies with the preservation of the forest trees and it also contributes in the pollination of wild and cultivated crops in the area. In Kaffa zone, wild coffee forest is the major crop pollinated by honeybees and contributes for maintenances of Coffee genetic resources. Samnegård *et al.* (2014) made a survey of coffee pollinators under different shade-tree structures found that the native honeybee (*Apis mellifera*) is the dominant visitor of coffee flowers and hence contributing in the pollination of coffee plants. Gesha-Sayilem forest has five plant communities that are found in different altitudinal gradient (Addi *et al.*, 2020). These are 1. *Ilex mitis-Syzygium guineense* community type. It occurs between altitudinal ranges of 1834-2408 m above sea level and found on the east facing slope. 2. *Pouteria adolfi-friederici-Schefflera abyssinica* community type. It occurs between 1734-2803 m above sea level and found on moderate slope facing towards south. 3. *Millettia ferruginea-Sapium ellipticum* community. It is found between 1722-2316 m a.s.l. and on gentle slope. 4. *Arundinaria alpine* community. It occurs between 2350-2506 m at lower slope (17.2%) facing to the south-west direction. 5. *Schefflera volkensi- Maesa lanceolate* community type. This community type is found between 1968 and 2800 m facing towards the north east (Addi, 2018). Despite the potentiality of the forest for honey production, there is lack of information on bee floral diversity and abundance. Therefore, the present study aimed to identify the major bee forage plants and diversity of bee flora in different plant communities of the Gesha and Sayilem districts of South-west Ethiopia.

MATERIALS AND METHODS

Study area

The study was carried out in Gesha-Sayilem forest. This forest is found in the two districts of Gesha and Sayilem in Kaffa Zone of Southern Nations Nationalities Peoples Regional State (Fig. 1). The southern part of Gesha district is bordered by Bita district in the west by the Sheka Zone, in the North by Ilubbabor Zone of Oromia Region and in the east by Gewata district.

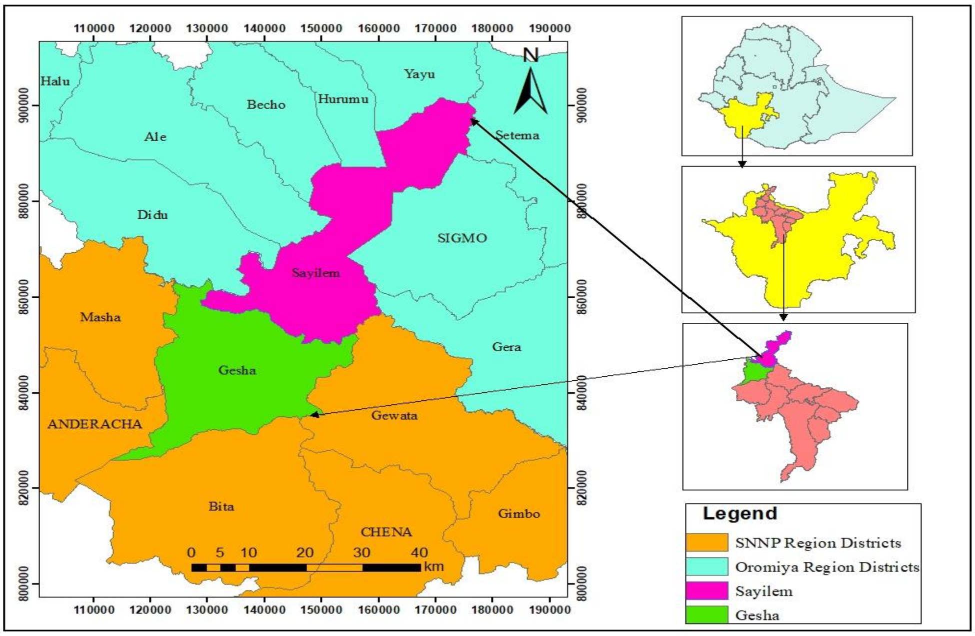

Figure 1. Map of the study area. [Source: Addi *et al.*, 2020]

Bee flora data collection

Systematic sampling design were employed on the basis of altitudinal gradients, because of the rugged and undulating nature of the topography of the area and its inaccessibility to collect of representative bee flora data. The quadrats were laid down with altitudinal difference of 200 m and all the plots were laid down 50 meter away from the road in order to avoid boundary effects. The sizes of quadrats were 625 m^2, 25 m^2 and 1 m^2 for trees, shrubs and lianas, and herbs, respectively, in a nested plot design (Kent & Coker, 1992; Kent, 2011). A total of 90 large quadrats were laid down, 18 quadrats in each of the plant communities of the forest (Addi *et al.*, 2020).

Plants visited by honeybees were observed in various sites of the study forest. During the observations, the types of food source offered by plants and the behavior of the honeybees while collecting nectar and pollen were noted (Bareke & Addi 2019a). Moreover, the flowering periods of plants visited by honeybees were also recorded throughout the year. Geographical Positioning System (GPS), plant press (flat wooden frames) including newspaper, ventilator cardboard, blotter with the size of 42 cm × 26 cm, secateurs (pruning scissors) and ethanol (70%) are materials used to collect and dry plant specimen for identification.

Pollen collection

This is used to identify plants that highly preferred by honeybees in addition to field observation. For this, a total of 10 modern beehives were placed in all plant communities, 2 in each plant community of the study area. Pollen traps having 16% pollen trapping efficiency were fitted at the entrance of beehives. Pollen loads were collected for one year (September 2017 to September 2018). A total of 300 samples of bee pollen loads were collected and used for the identification of the botanical origin of the pollen. The pollen loads were sorted by color and then, slide prepared for the identification. Photographs of different views of the pollen grains were taken using Zeiss light microscope magnification power of 40X linked with computer software (Fig. 2).

Figure 2. A, Modern bee hive fitted with pollen trap; **B**, Sorted pollen into homogenous color; **C**, Slide preparation; **D**, Stored slide in slide box; **E**, Pollen under identification using Zeiss light microscope.

Richness and diversity of bee forage plants

Species diversity of plants was quantified in different plant communities using Shannon-Wiener diversity index; species richness and Shannon's evenness. Shannon-Wiener diversity index is the most popular measure of species diversity that cannot be affected by sample size.

The Shannon-Wiener Index is used to calculate the diversity of bee plants (Ramirez-Arriaga *et al.*, 2011).

$$\text{Shannon Index } (\mathbf{H'}) = -\sum_{i=1}^{s} (\text{Pi} \times \text{lnPi})$$

Where, H'= Shannon diversity index; *s*= Number of species; *i* = 1; Pi = Proportion of individuals or the abundance of the i^{th} species; ln = log base n.

$$\text{Evenness } (\mathbf{J}) = \frac{\text{H}'}{\text{H}'max} = \frac{\text{H}'}{ins}$$

Where, H'= Shannon-Wiener diversity index; H'max= ln s where s is the number of species; ln= log $base_n$; Value of evenness is ranged from 0 to 1 (Kent & Coker, 1992).

Floristic similarity analysis

Plant communities can differ in species composition; richness and relative abundance of species (evenness). To estimate the similarity between the communities a number of different similarity indices were applied. Similarity coefficients measure the degree to which the species compositions of quadrats or samples are alike (Kent & Coker, 1992). Sorensen similarity (Ss) coefficient is a widely used index that gives more weight to the common species of the samples (Kent & Coker, 1992). The similarity coefficient value ranges from 0 (complete dissimilarity) to 1 (total similarity). In this comparison, β-diversity between community types was also computed using the formula β-diversity, Where a is the number shared species between two sites, and b and c are the numbers of species unique to each site. High species turnover would indicate high β-diversity or a low level of similarity. Thus, the floristic similarity of the community types in the present study was assessed using the Sorenson's coefficient of similarity using statistical program in R software (R Core Development Team 2011).

$$\text{The formula for Sorensen similarity } (\boldsymbol{Ss}) = \frac{2a}{2a+b+c}$$

Where, a= Number of species common to both community types; b= Number of species in one of the community to be compared; c= Species present in the other site.

RESULTS AND DISCUSSION

Bee forage composition and diversity

Based on bee plant inventory, observation and pollen load collection a total of 93 plant species belong to 43 families were identified (Table 1). The growth forms of bee forage utilized by honeybees comprise 36.6% herb, 25.8% shrubs, 23.6% trees and 14% climbers (Fig. 3). Similar study conducted in Zerat Afromontane Forest in North Shewa Zone of Amhara Regional State of Ethiopia (Abebe & Temam, 2016) and in Gurage Mountains reported that herbs account for a large proportion of plants encountered in the forests (Tamru, 2014). Asteraceae family has the highest species comprising 20 species (21.5%) and followed by Lamiaceae and Fabaceae 5 (5.4%) each in the area (Fig. 4). Study conducted in Gera forest also indicates that Asteraceae is the most frequent family, represented by the highest species composition in the area (Bareke & Addi, 2019a). However, a study conducted by Yohannes *et al.* (2015) in the Gera forest indicates that the Fabaceae family is dominant while Asteraceae is the second dominant. This study was not done in view of beekeeping and it was about general floristic composition of the forest. All species of Fabaceae family are not bee forage plants. Due to this, it is not a dominant honeybee plant family in different forest area. But, in view of beekeeping Asteraceae family is the dominant bee forage family in many forest areas; this could be attributed to the potential of its species for honey production. Figure 5 shows the photographed images of some bee forage plants inventoried and identified in in Gesha-Sayilem forest.

Table 1. Checklist of plant species identified from the study area.

Plant species	Family	Habit	Flowering period	Food source
Acanthopale ethio-germanica Ensermu	Acanthaceae	Herb	Sep-Nov	N&P
Acanthus eminens C.B. Clarke	Acanthaceae	Herb	Sep-Nov	N&P
Achyranthes aspera L.	Amaranthaceae	Herb	Aug-Dec	P
Achyrospermum schimperi (Hochst. ex Briq.) Perkins	Lamiaceae	Herb	Sep-Oct	P
Acmella caulirhiza Del.	Asteraceae	Herb	Sep-Nov	N&P
Aframomum corrorima (Braun) Jansen	Zingiberaceae	Herb	Jun-Jul	N&P
Ageratum conyzoides L.	Asteraceae	Herb	Sep-Dec	N&P
Albizia gummifera (J.F.Gmel.) C.A.Sm	Fabaceae	Tree	Jan-Apr	N&P
Allophyllus abyssinicus (Hochst.) Radlk.	Sapindaceae	Tree	Sep-Oct	N&P
Andropogon abyssinicus Fresen	Poaceae	Herb	Sep-Oct	P
Apodytes dimidiata E. Mey. ex Arn.	Icaccinaceae	Tree	Sep-Nov	N&P
Aspilia mossambicensis (Oliv.) Wild	Asteraceae	Herb	Sep-Nov	N&P
Basella alba L.	Basellaceae	Climber	Sep-Oct	N&P
Bersama abyssinica Fresen.	Melianthaceae	Tree	Sep-Nov	N&P
Bidens prestinaria (Sch. Bip.) Cufod.	Asteraceae	Herb	Sep-Nov	N&P
Bothriocline schimperi Olivo & Hiern ex Benth.	Asteraceae	Herb	Sep-Dec	N&P
Brassica carinata A. Br	Brassicaceae	Herb	Sep-Oct	N&P
Brucea antidysenterica J. F. Mill.	Simaroubaceae	Shrub	Sep-Oct	N&P
Buddleja polystachya Fresen.	Loganiaceae	Shrub	Sep-Oct	N&P
Celtis africana Burm. f.	Ulmaceae	Shrub	Sep-Nov	N&P
Circium schimperi (Yatke) C. Jeffrey cufod	Asteraceae	Herb	Sep-Oct	P
Clausena anisata (Wild.) Benth.	Rutaceae	Shrub	Sep-Dec	N&P
Clematis simensis Fresen.	Ranunculaceae	Climber	Sep-Dec	N&P
Coffea arabica L.	Rubiaceae	Shrub	Feb-Mar	N&P
Croton macrostachyus Del.	Euphorbiaceae	Tree	Apr-June	N&P
Datura innoxia Mill.	Solanaceae	Shrub	Sep-Mar	N&P
Dombeya torrida (J.F. Gmel.) P.Bamps	Sterculiaceae	Tree	Sep-Nov	N&P
Ehretia cymosa Thonn.	Boraginaceae	Shrub	Sep-Dec	N&P
Eucalyptus camaldulensis Dehnh	Myrtaceae	Tree	Mar-Apr	N&P
Eucalyptus globulus Labill	Myrtaceae	Tree	Mar-Apr	N&P
Ekebergia capensis Sparrm.	Meliaceae	Tree	Jan-Feb	N&P
Galiniera saxifraga (Hochst.) Bridson	Rubiaceae	Shrub	Sep-Dec	N&P
Galinsoga quadriradiata Ruiz & Pavon	Asteraceae	Herb	Sep-Oct	N&P

Glycine wightii (Wight & Am.) Verdc.	Fabaceae	Climber	Sep-Dec	N&P
Gouania longispicata Engl.	Rhamnaceae	Climber	Sep-Dec	N&P
Guizotia scabra (Vis.) Chiov.	Asteraceae	Herb	Sep-Nov	N&P
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	Tree	Oct-Dec	N&P
Helichrysum formosissimum Sch. Bip. ex A. Rich	Asteraceae	Herb	Sep-Oct	N&P
Hibiscus berberidifolius A. Rich.	Malvaceae	Shrub	Sep-Oct	N&P
Hibiscus ludwigii Eckl. & Zeyh.	Malvaceae	Shrub	Sep-Oct	N&P
Hypericum revolutum Vahl	Hypericaceae	Shrub	Sep-Oct	N&P
Hypoestes triflora (Forssk.) Roem & Schult	Acanthaceae	Herb	Sep-Oct	N&P
Ilex mitis (L.) Radlk.	Aquifoliaceae	Tree	Sep-Oct	N&P
Impatiens ethiopica Grey-Wilson	Balsaminaceae	Herb	Aug-Oct	N&P
Ipomea purpurea (L.) Roth.	Convolvulaceae	Climber	Sep-Oct	N
Ipomea indica (Burm.f) Merrill	Convolvulaceae	Climber	Sep-Oct	N&P
*Isoglossa somalensi*s Lindau	Acanthaceae	Herb	Sep-Dec	N&P
Jasminum abyssinicum Hochst. ex DC	Oleaceae	Climber	Dec-Jan	N&P
Justicia schimperiana (Hochst. ex Nees) T. Anders.	Oleaceae	Climber	Sep-Dec	N&P
Laggera crispata Vahl Hepper & Wood	Asteraceae	Herb	Sep-Oct	P
Maesa lanceolata Forssk.	Myrsinaceae	Shrub	Sep-Oct	N&P
Malva verticillata L.	Malvaceae	Herb	Sep-Nov	N&P
Maytenus undata (Thunb.) Blaelock	Cleastraceae	Shrub	Sep-Nov	P
Mikaniopsis clematoides (S'ch. Bip. ex A. Rich.) Milne-Redh.	Asteraceae	Climber	Sep-Nov	N&P
Millettia ferruginea (Hochst.) Bak.	Fabaceae	Tree	Dec-Jan	N &P
Nuxia congesta R. Br. ex Fresen.	Loganiaceae	Shrub	Sep-Nov	N &P
Ocimum sp.	Lamiaceae	Herb	Sep-Nov	N&P
Olea welwitschii (Knobl.) Gilg & Schellenb.	Oleaceae	Tree	May-Jun	N &P
Pentas schimperiana (A. Rich.) Vatke	Rubiaceae	Shrub	Sep-Oct	N&P
Periploca linearifolia Quart. Dill & A. Rich.	Asclepiadaceae	Climber	Sep-Dec	N&P
Phoenix reclinata Jacq.	Arecaceae	Tree	Sep-Dec	N&P
Phytolacca dodecandra L 'Herit.	Phytolaccaceae	Climber	Sep-Dec	N&P
Piper capense L.	Piperaceae	Herb	Apr-June	P
Plantago lanceolata L.	Plantaginaceae	Herb	Oct-Dec	P
Polyscias fulva (Hiern) Harms	Araliaceae	Tree	Oct-Dec	N&P
Pouteria adolfi-friederici (Engl.) Baehni	Sapotaceae	Tree	May-Jun	N
Premna schimperi Engl.	Verbenaceae	Shrub	Sep-Oct	N&P
Prunus africana (Hook. f.) Kalkm.	Roseaceae	Tree	Sep-Oct	N&P
Psycnostachys eminii Gurke	Lamiaceae	Herb	Sep-Dec	N&P
Ranunculus multifidus Forssk.	Ranunculaceae	Herb	Sep-Dec	N&P
Rhamnus prinoides L'Herit.	Rhamnaceae	Herb	Sep-Dec	N&P
Rothmannia urcelliformis (Hiern) Robyns	Rubiaceae	Shrub	Sep-Dec	N
Rubus steudneri Schweinf.	Roseaceae	Climber	Sep-Dec	N&P
Salix subserrata Willd.	Salicaceae	Shrub	Sep-Dec	N&P
Salvia nilotica Juss. ex Jacq.	Lamiaceae	Herb	Sep-Oct	N&P
Sapium ellipticum (Hochst.) Pax	Euphorbiaceae	Tree	Oct-Dec	N&P
Satureja paradoxa (Vatke) Engl.	Lamiaceae	Herb	Sep-Oct	N&P
Schefflera abyssinica (Hochst ex A. Rich) Harms	Araliaceae	Tree	Ma-Apr	N &P
Schefflera volkensi (Engl.) Harms	Araliaceae	Tree	Ma-Apr	N&P
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	Herb	Sep-Dec	N&P
Solanecio mannii (Hook. f.) C. Jeffrey	Asteraceae	Shrub	Sep-Dec	P
*Sphaeranthus suaveolen*s (Forssk.) DC.	Asteraceae	Herb	Sep-Dec	N&P
Syzygium guineense (Willd.) DC.	Myrtaceae	Tree	Feb-Mar	N&P
Trifolium polystachyum Fresen.	Fabaceae	Herb	Sep-Oct	N&P
Vepris dainellii Pic.Serm	Rutaceae	Tree	Dec-Jan	P
Vernonia amygdalina Del	Asteraceae	Shrub	Dec-Jan	N&P
Vernonia auriculifera Hiern	Asteraceae	Shrub	Dec-Jan	N&P
Vernonia hochstetteri Sch. Bip. ex Walp.	Asteraceae	Shrub	Dec-Jan	N&P
Vernonia ituriensis Muschl.	Asteraceae	Shrub	Dec-Jan	N&P
Vernonia leopoldi (Sch. Bip. ex Walp.) Votke	Asteraceae	Shrub	Dec-Jan	N&P
Vernonia wollastonii S'. Moore	Asteraceae	Climber	Dec-Jan	N&P
Vicia faba L.	Fabaceae	Herb	Sep	N&P
Zea mays L.	Poaceae	Herb	Aug-Sep	P

Note: P- Pollen, N- Nectar, N & P- Nectar and Pollen.

From the identified 93 bee plants 85% of them provide both nectar and pollen sources while 11.8% were pollen sources and 3.2% nectar sources (Table 1). This indicated that pollen source plants are numerous than nectar sources. Nectar is used for honey production while pollen is for colony multiplication. Therefore, nectar source plants were fewer as compared to pollen sources. Not all bee plants are equally important to honeybees as well as for honey production. The sources of most of the world's honey are only about 16% of the flowering plants (Crane, 1990). This indicates that for every geographical region there are very few important honey source plants.

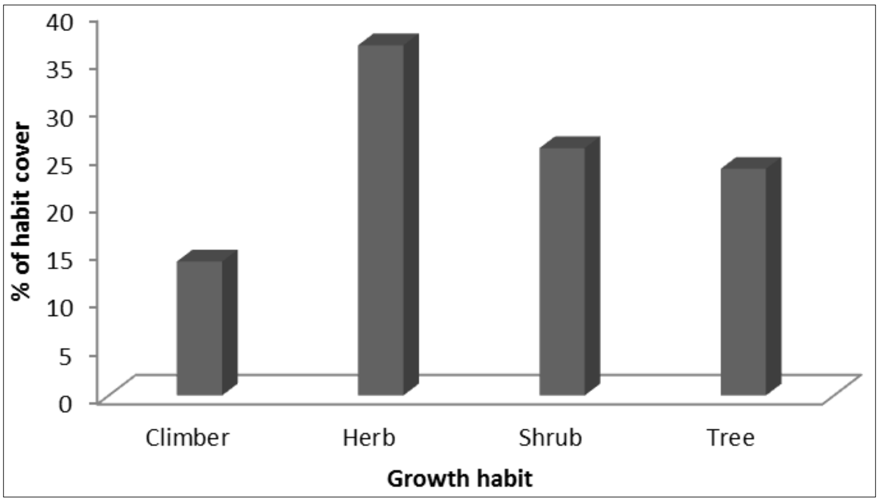

Figure 3. The growth habit of bee forages in the study area.

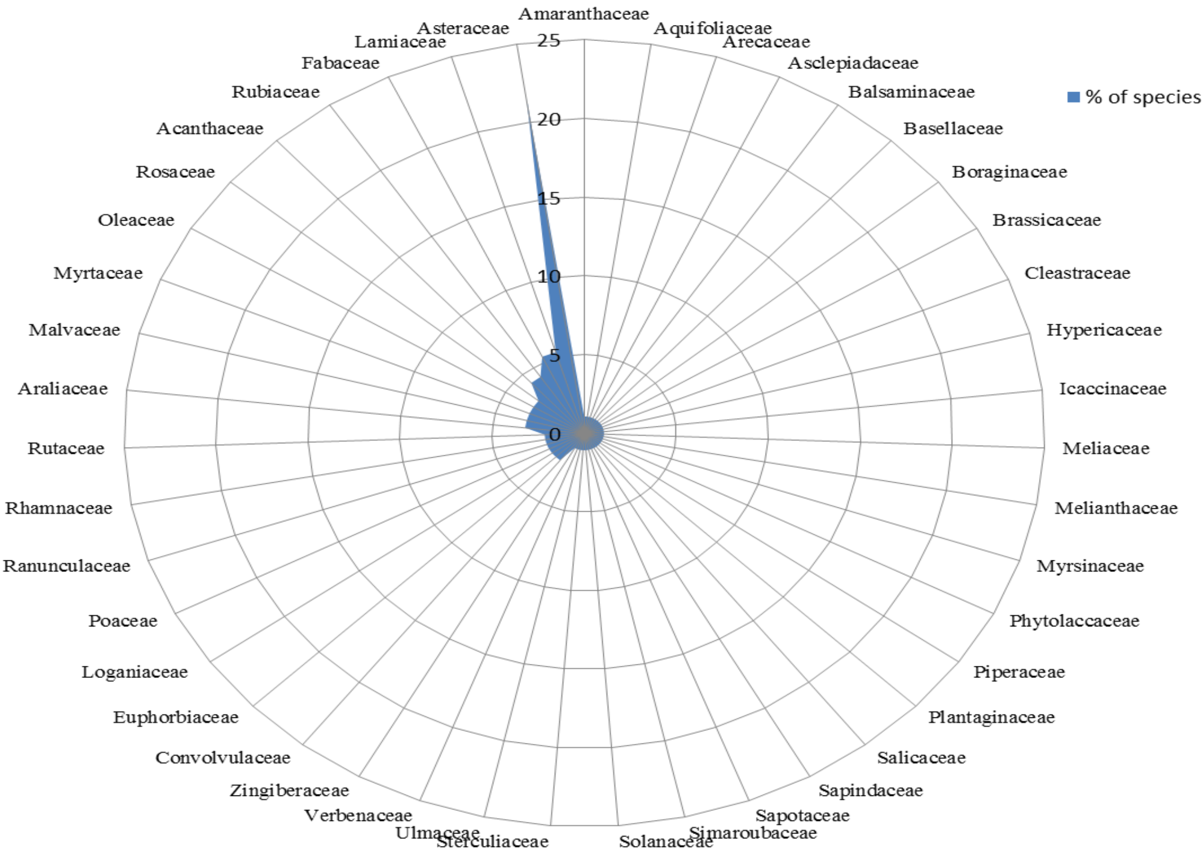

Figure 4. Percentages of plant species from different families identified in the forest.

The south-western parts of the country have relatively high percentage of forest cover that makes the area highly suitable for beekeeping. According to the secondary data collected from the District office of the Ministry of Agriculture, the forest cover varies from 22% to 70% of the total land area which makes the area is an ideal for beekeeping. In this study, relatively smaller bee forage species compositions were recorded as compared to the floristic richness of the forest in the area. This is attributed due to a floral preference of honeybees, nectar and pollen production of the plants and climatic factors of the area. Asteraceae has the highest species richness comprising followed by

Lamiaceae and Acanthaceae. A similar study conducted by Addi & Bareke (2019) and Bareke & Addi (2019a) reported that Asteraceae is the most frequent families represented by the highest number of bee forage species. The dominance of the Asteraceae family could be attributed to the potential of its species for honey production (Bareke & Addi 2019a). However, many authors have mentioned that Fabaceae the dominant family (Gurmessa *et al.*, 2013; Kuma & Shibru, 2015). This is not in view of beekeeping rather general floristic composition because there are many Fabaceae species that are not bee forage. On the other hand, the dominant family is varied from place to place.

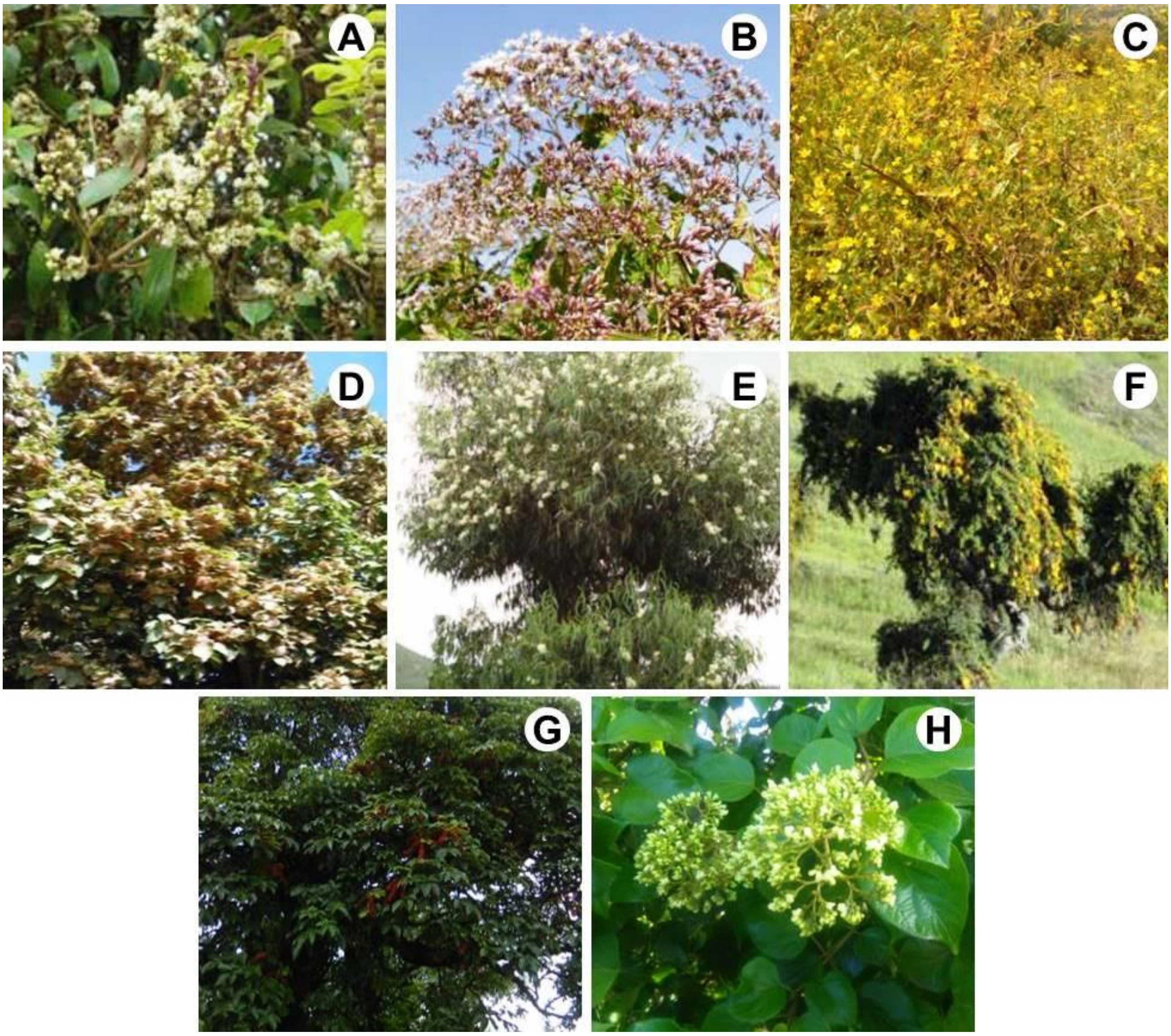

Figure 5. Some bee forage plant species in vegetation communities of Gesha-Sayilem forest in Kaffa Zone, south-western Ethiopia: **A**, *Ilex mitis* (L.) Radlk.; **B**, *Vernonia auriculifera* Hiern; **C**, *Guizotia scabra* (Vis.) Chiov.; **D**, *Dombeya torrida* (J.F. Gmel.) P.Bamps; **E**, *Eucalyptus globulus* Labill; **F**, *Hypericum revolutum* Vahl; **G**, *Schefflera abyssinica* (Hochst ex A. Rich) Harms; **H**, *Premna schimperi* Engl.

Species diversity

The analysis of bee forage diversity using Shannon-Wiener diversity index found in different plant communities was indicated in table 2. Accordingly, the plant community one, two and three has the highest bee plant diversity 3.2, 3.2 and 3.5, respectively. Relatively lower species diversity and species richness were recorded for community four and five (2.1 and 2.3) respectively. Community one, two and three have highest species richness (55, 55 and 45) respectively and lower number of species recorded for the communities four and five (14 and 11 respectively). The dominant bee forages for honey production in community one were (*Ilex mitis* (L.) Radlk, and *Syzygium guineens* (Willd.) DC.), community two (*Pouteria adolfi-friederici* (Engl.) Baehni, and *Schefflera abyssinica* (Hochst ex A. Rich) Harms), Community three (*Millettia ferruginea* (Hochst.) Bak., and *Sapium ellipticum* (Hochst.) Pax), community four (*Hagenia abyssinica* (Bruce) J.F. Gmel. and *Dombeya torrida* (J.F. Gmel.) P.Bamps.), community five (*Schefflera volkensi* (Engl.) Harms and *Maesa lanceolata* Forssk.) plant community. Study conducted by Bareke & Addi (2018) in Guji zone indicates that *Syzygium guineense* (Willd.) DC., *Ilex mitis* (L.) Radlk and *Schefflera abyssinica* (Hochst ex A.

Rich) Harms are the major bee forage plants that can provide monofloral honey. The high diversity of bee flora resource was found in from community one to *three*. According to study conducted by Addi *et al.* (2020), in community 1 the dominant tree species were *Allophyllus abyssinicus* (Hochst.) Radlk, *Croton macrostachyus* Del. and *Apodytes dimidiata* E. Mey. ex Arn. while the shrubs include *Galiniera saxifraga* (Hochst.) Bridson, *Brucea antidysenterica* J. F. Mill and *Clausena anisata* (Wild.) Benth. The herb layer comprises *Hypoestes triflora* (Forssk.) Roem & Schult and *Achyranthes aspera* L. Community 2 is dominated in the upper canopy by *Schefflera abyssinica* (Hochst ex A. Rich) Harms, *Albizia gummifera* (J.F.Gmel.) C.A.Sm, *Ekebergia capensis* Sparrm., and *Ilex mitis* (L.) Radlk. trees and they are major bee forage plants in the area. *Vernonia auriculifera* Hiern the dominant bee forage shrub in the community 2. The herb layer is dominated by *Acanthus eminens* C.B. Clarke and *Piper capense* L. The dominant trees in the community 3 are *Millettia ferruginea* (Hochst.) Bak., *Olea welwitschii* (Knobl.) Gilg & Schellenb, *Albizia gummifera* (J.F.Gmel.) C.A.Sm., *Polyscias fulva* (Hiern) Harms and *Sapium ellipticum* (Hochst.) Pax while shrubs include *Vepris dainellii* Pic.Serm and *Coffea arabica* L. as well as *Aframomum corrorima* (Braun) Jansen bee forage herb in the area. The climbers/lianas include *Clematis simensis* Fresen, and *Jasminum abyssinicum* Hochst. ex DC. Many authors have been reported that *Schefflera abyssinica* (Hochst ex A. Rich) Harms, *Ilex mites* (L.) Radlk, *Vernonia auriculifera* Hiern, *Croton macrostachyus* Del, *Coffea arabica* L., *Syzygium guineense* (Willd.) DC., *Clematis simensis* Fresen, *Hypoestes triflora* (Forssk.) Roem & Schult and *Albizia gummifera* (J.F.Gmel.) C.A.Sm. are the major bee forage plants in different parts of Ethiopia (Bareke & Addi, 2018; Bareke & Addi 2019b; Bareke *et al.*, 2020).

Table 2. The bee forages diversity in Gesha-Sayilem forest in different plant communities.

Communities	Richness	Shannon	Evenness
Community one	55	3.2	0.82
Community two	45	3.2	0.86
Community three	55	3.53	0.88
Community four	14	2.32	0.89
Community five	11	2.1	0.89

Similarity among the plant communities

Pair’s wise comparison of the Sorensen similarity coefficient gave a higher value between the plant communities comprising bee forages table 2. Accordingly, the communities 1, 2, 3 and 5 are more similar to each other as shown in table 3. Community four is with a similarity ratio of 0.29 can be considered to be less similar from other communities. On the other hand, the beta diversity for communities 1, 2, 3 and 5 were 0.25, 0.27, 0.39 and 0.28 respectively while community four has a higher beta diversity index (0.71) indicating low similarity with rest of the plant communities. The analysis of species composition for each community indicated that community one, two and three had the highest species composition (92, 96, 88) respectively followed by community four and five (30 and 70) respectively.

Table 3. Pairwise comparison of similarity index between the community groups.

Plant community	Community 1	Community 2	Community3	Community4	Community5
1	1	0.74 (0.26)	0.68(0.32)	0.33(0.67)	0.51(0.49)
2	0.75 (0.25)	1	65(0.35)	0.26(0.74)	0.45(0.55)
3	0.73 (0.27)	0.66 (0.34)	1	0.24 (0.76)	0.46(0.54)
4	0.29 (0.71)	0.28.3(0.72)	0.25(0.75)	1	0.38(0.62)
5	0.39 (.0.41)	0.40(0.60)	0.42(0.58)	0.22(0.88)	1

Note: Numbers in bracts indicate β-diversity.

Pollen load analysis

The highest proportion of pollen loads were collected from *Guizotia scabra* (Vis.) Chiov, (20.5%), *Bidens prestinaria* (Sch. Bip.) Cufod (13.5%), *Croton macrostachyus* Del. (12.7%), *Datura innoxia* Mill. (11.1%), *Syzygium guineense* (Willd.) DC (7.2%), *Eucalyptus globulus* Labill (6.5%), *Plantago lanceolata* L. (5.3%), *Vernonia amygdalina* Del. (4.5%) and *Maesa lanceolata* Forssk. (3.7%) and the rest of the plants contributing for little proportion (Fig. 6). About 42.3% of pollen was collected from September-November, 32.2% from December to January, 18.9% during March to May and 6.2% of pollen during June to August. Among the flowering plant species, *Eucalyptus camaldulensis* Dehnh, *Datura innoxia* Mill., *Apodytes dimidata* E. Mey. ex Arn., *Olea welwitschii* (Knobl.) Gilg & Schellenb had the longest flowering period and provided continuous nectar and pollen supply for foraging honeybees.

Out of the total identified bee forages only thirty-six plant species were identified as the source of the pollen. The highest proportion of pollen comes from only a few plants mainly from forest trees, weeds and hedge plants. These included *Guizotia scarba* (Vis.) Chiov., *Vernonia auriculifera* Hiern, *Datura innoxia* Mill. (introduced and planted a live fence), *Trifolium polystachya* Fresen, *Zea mays* L., *Ilex mitis* (L.) Radlk., *Apodytes dimidiata* E. Mey. ex Arn. and *Croton macrostachyus* Dell. The rest of plant species may contribute little amount of pollen or provide a high amount of nectar. The amount and diversity of pollen were influenced by season but not by landscape diversity (Danner *et al.*, 2017). The diversity of collected pollen is important for honeybee health (Alaux *et al.*, 2010). It is an essential for the growth, development and reproduction of honey bee colonies (Di Pasquale *et al.*, 2013). A study conducted by Piroux *et al.* (2014) also reported that the foraging distances as well as the amount and diversity of the pollen diet are affected by the types of plants found in landscape. Less diverse landscapes with lower bee forage resource availability lower input and diversity of the pollen.

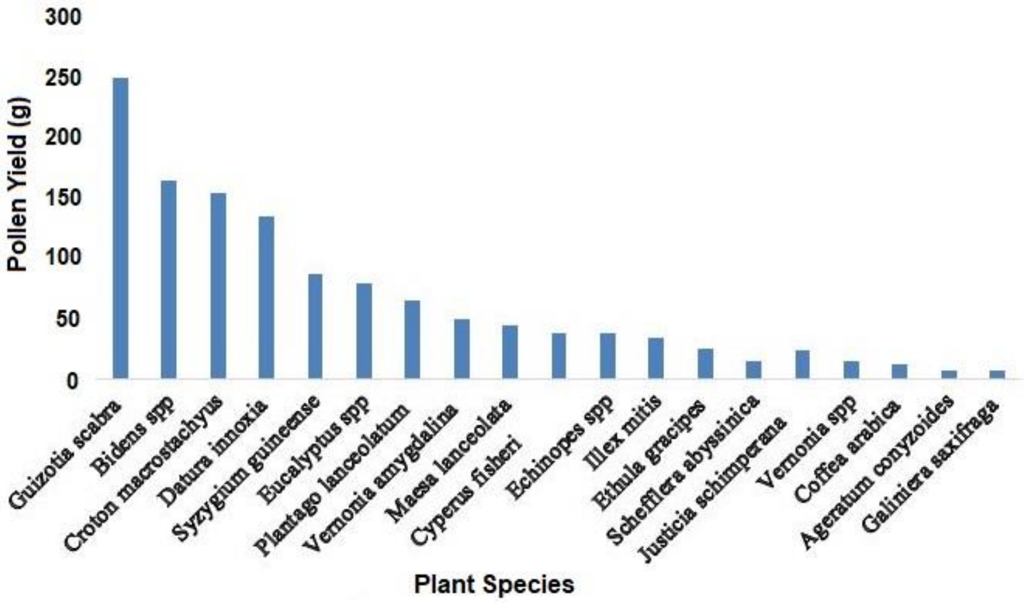

Figure 6. Pollen yields of bee forages.

The highest pollen load is collected from September to January and April to May and lowest during dry and rainy months (February and July). The highest pollen yield was obtained during October and November due to the fact that the majority of plant species flower after the long rainy season (June-August) and the short rainy season (March to April) reaching peak in October and April. A similar study conducted by Bareke & Addi (2019a) in Gera forest indicated that the majority of pollen source plants are flowered in September to October. On the other hand, the lowest pollen yield was recorded June to August which is the main rainy season in the area. The rain affects the flight conditions of honeybees which in turn reduces their capacity for pollen collection. Similar study has been reported by Lamessa *et al.* (2008) during the rainy season, low temperatures possibly inhibit the growth and flowering of the plant species whereas the higher temperature during the dry period result in water deficiency in plants resulting in low nectar secretion and pollen collection.

CONCLUSION

In conclusion, this forest has the high diversity of bee flora resource. The beekeepers should follow the flowering calendar of the plant to harvest honey, sequentially.

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