Bee flora resources and honey production calendar of Gera Forest in Ethiopia

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Abstract. Bareke T, Addi A. 2019. Bee flora resources and honey production calendar of Gera Forest in Ethiopia. Asian J For 3: 69-74. Gera forest contains substantial coverage of natural forest and known as a Key Biodiversity Hotspot area for Coffea arabica conservation and one of the potential areas for beekeeping. The study was carried out to assess the bee flora and flowering calendar to harvest more honey following the flowering plant cycle. Semi-structured questionnaires, participatory Rural Appraisal (PRA) techniques, and field observation were used for data collection. Honey samples collection was also made to identify the botanical origin of honey through honey pollen analysis. Seventy-four bee plant species were identified, which belongs to 41 families. Among the identified plant families, Asteraceae (29.3%), Lamiaceae (14.6%), Acanthaceae (12.2%), and Fabaceae (9.8%) are the most frequent families, represented by the highest species composition in the area. Four major honey harvesting durations were identified (January, March, April, and early June for Vernonia, Coffee, Schefflera, and Croton honey respectively) using the flowering calendar in Gera Forest. The pollen analysis of honey revealed that four types of monofloral honeys were identified comprising Schefflera abyssinica, Vernonia amygdalina, C. arabica and Croton macrostachyus in Gera forest. This is due to their abundance and potentiality for honey production. Therefore, the beekeepers should follow the flowering calendar of the plant to exploit the potential of the forest for honey production. Furthermore, market promotion for monofloral honeys of the Gera forest should be made as an incentive for the beekeepers to sell honey with premium prices and branding and labeling of honey of the area

Keywords: Bee forage, floral calendar, honey, monofloral honey, pollen analysis

INTRODUCTION

Ethiopia has a substantial potential for beekeeping development. The ideal climatic conditions, diversified floral resources, and huge water bodies allow the country to sustain around 10 million honeybee colonies (Amsalu et al. 2004). Beekeeping contributes to food security through pollination, economic and natural resource conservation, and creating better employment opportunities (Admassu et al. 2014a; Tura et al. 2014; EIAR 2016; Tura et al. 2018; Tura and Admassu 2019a). Despite Ethiopia’s great potential for beekeeping in general and the beekeepers, in particular have not yet well benefited from the subsector. This is mainly attributed to the inadequate introduction of improved technologies and skills that enhances the quantity and quality of bee products. Currently, Oromia Region represents approximately 70% of the forest resources of the country, and its closed high forests are diminishing due to shifting cultivation, fuelwood collection, urbanization, and logging (CSA 2015). However, the region still contributes the highest for honey production in Ethiopia. According to CSA (2015), the Oromia region contributes 41% of the total honey production of the country.

Gera forest is one of the remaining forest resources in the southwestern part of Oromia. The Gera forest contains substantial coverage of natural forest and known as a Key Biodiversity Hotspot Area for Coffea arabica conservation and potential area for beekeeping (Kitessa 2007). Apart from its dense natural forest, the district is dominated by agroforestry plants such as spices and fruit trees. As a result, a large volume of honey is produced annually. In addition to this, honey is an important source of income for smallholder farmers in the area (Chala et al. 2012). Even though the forest has a lot of major bee flora, the beekeepers of the area could not understand the flowering calendar of the honeybee plants.

A flowering calendar is a time table for a beekeeper that indicates the approximate date and duration of the blossoming periods of the important honey and pollen plants (Diver 2002; Tura and Admassu 2018). Knowledge of seasonal availability, length of flowering, and flowering phenology of honeybee plants is very important to boost the production of honey. The seasonal cycles of honeybee colonies are related to the calendar of bee plants in such a way that it will be applied in practical seasonal colony management (Fichtl and Admassu 1994; Admassu et al. 2014b; Tura and Admassu 2018). The timing of management operations corresponding to a phenological pattern of bee plants of the area is critical in building up colony populations before the main nectar flow. Even though bees naturally build up their population during periods when resources are available, the beekeeper must ensure that peak population size before or during the nectar flow. Hence, the flowering calendar is an important tool for determining various beekeeping management operations such as when to suppersing and reducing, time of...
supplementary feed, insert queen excluder, transferring time, honey harvesting time, and honeybee colony migration time.

So far, there is limited information about honeybee plants and floral calendar of the Gera forest. Therefore, the main objective of this study was to assess honeybee plants and flowering calendar that enables the beekeepers to harvest honey sequentially following the seasonal flowering cycle.

MATERIALS AND METHODS

Description of the study area
Gera Forest is found in Gera District approximately 100 km to the west of Jimma, located in the southwestern part of Ethiopia. Gera forest consists of undulating hills, and the altitudinal ranges 1,000-3,000 m with steep mountainous terrain in some places (Bruck 2015). It has a total area of 80,830.4 ha (Yohannes et al. 2015). The soil in the forest is dystric nitosol type, which is deep, clay red soil (GDARDO 2012). The mean annual temperature is about 18.4°C, while the mean annual rainfall is 1805 mm year -1 (NMSA 2013). Gera Forest contains a number of flowering plant species that are endemic to Ethiopia. Based on the published Flora of Ethiopia, seven endemic species have been identified (Yohannes et al. 2015). In the Gera forest, there are five plant communities. These are Vernonia auriculifera-Prunus africana community type, Schefflera abyssinica-Maytenus arbutifolia community type, Coffea arabica-Olea capensis community type, Syzygium guineense-Galinierea saxifraga community type and Croton macrostachyus-Albizia gummifera community type (Yohannes et al. 2015).

Data collection
Primary data was collected using semi-structured questionnaires, participatory Rural Appraisal (PRA) techniques, and field observation. The focus group discussions with experts, development agents, and beekeepers, were conducted to generate relevant information. The information focused on honey production potential, major honey source plants, major honey types, honey harvesting periods, and frequency and honey yield per hive. Field observation was made on bee floras of the forest to identify the plant and the food source provided for bees during the flowering period. A total of 12 pure honey samples (3 samples per harvesting month) were collected during honey flow seasons that have a similar climatic condition. Accordingly, December to February (January), March to May (March and April), and June August (start of June) from the farm gate of the beekeepers. For each honey collection site, three honey samples were purchased. Each honey sample was weighed 500 g. The samples were then stored at 4°C for further analysis (Tura and Admassu 2019b).

Honey pollen analysis
For honey pollen analysis, the method recommended by the International Commission for Bee Botany (Louveaux et al. 1978) was adopted. Ten grams of each honey was dissolved in 20 ml of warm water (40°C). The solution was centrifuged for 10 min at 2500 r/min, the supernatant solution was decanted, and the sediments were collected into a conical tube for the study (Erdtman 1960). The sediments were rinsed with distilled water to enhance further extraction of pollen from honey, centrifuged for 5 min at 2500 r/min, and preserved for study. To analyze the pollen content of the honey samples, two slides were prepared from each sample, and the picture of the pollen was taken by the camera connected to the microscope (Carl ZEISS microscope Germany). Pollen types were identified by comparison with reference slides of pollen collected directly from the plants in the study area. For quantification of the pollen types, at least 500 pollen grains were counted from each sample (Oliveira et al. 2010). The percentage frequency of the pollen taxa in all the samples was calculated, excluding polleniferous plant species, which were observed during honey pollen analysis. The types of pollen were allocated to one of four frequency classes for nectar source plants; predominant pollen types (>45% of the total pollen grains counted); secondary pollen types (16%-45%); important minor pollen types (3%-15%); and minor pollen types (3%) (Louveaux et al. 1978). Honeys with predominant pollen types were considered as monofloral. Finally, descriptive statistics were used to analyze the collected data.

RESULTS AND DISCUSSION

Pollen analysis of honey
The pollen analysis of honey from 12 monofloral honeys of the Gera forest indicated that 13 plant species were identified, ranging from 2% to 60% of the pollen count. The monofloral honey of C. arabica was contributed by four plant species (C. arabica, Vernonia amygdalina, Rumex spp, and Vernonia auriculifera (Figure 1). C. arabica honey is a new emerging monofloral honey in the area and produced in Coffee agroforestry and forest coffee production system. It has a very short flowering period usually stays in flower for 5 to 7 days, and C. arabica honey is mostly harvested in February to March.

Vernonia honey was mainly dominated by V. amygdalina (Ebicha), and the pollen count from honey ranges from 1.9 % to 50.4%. The other bee forage plants contributing for Vernonia monofloral honey were Eucalyptus spp., C. arabica, Vernonia auriculifera (Rejji) and Caesalpinia decapetala (Figure 1). Vernonia honey is very dark in color even after crystallization, and it tends to granulate uniformly. The honey has a very strong flavor and bitter test, traditionally the honey is well known for its medicinal property (Admassu et al. 2014b).
The honey of Schefflera was harvested from April to May after the minor rainy season. Schefflera honey was mainly dominated by Schefflera abyssinica. The pollen count from S. abyssinica honey ranges from 2% to 59% in which pollen count percentage of S. abyssinica was 59%. C. arabica, Eucalyptus spp., Justicia spp., Syzygium guineense and Croton macrostachyus were other bee plants that contributed to this honey production (Figure 2). The honey from this plant is extra white with a characteristic aroma and a very pleasant test.

On the other hand, the honey of Croton was harvested in June at the end of the minor rainy season. Croton honey was comprised of 5 species of which C. macrostachyus, Eucalyptus globulus, Cyperus fischerians, Ekebergia capensis, and Olea welwitschii are the species contributing for croton honey in which the highest pollen count percentage was the C. macrostachyus (60%) (Figure 2). Monofloral honeys of S. abyssinica and C. macrostachyus species produced because of their abundance in addition to their potential for honey production. Tura and Admassu (2018) also reported that the dominancy of monofloral honey source plant species in honey samples was due to their abundance and nectar potentiality.

Pollen pictures of major bee flora plants, providing monofloral honeys in the Gera forest are presented in Figure 3.

**Bee flora resources in Gera forest**

The result of the study revealed that 74 honeybee forages were identified, which belongs to 41 families. Among the identified plant families, Asteraceae (29.3%), Lamiaceae (14.6%), Acanthaceae (12.2%), and Fabaceae
(9.8%) are the most frequent families, represented by the highest species composition in the area. Admassu and Tura (2019) also reported that Asteraceae, Acanthaceae, Fabaceae, Rubiaceae, Poaceae, Lamiaceae, and Euphorbiaceae are the most frequent families, represented by the highest number of bee forage species (Table 1). 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. All species of Fabaceae family are not bee forage plants. Due to this, it is not a dominant honeybee plant family in the Gera forest. On the other hand, the dominance of the Asteraceae family could be attributed to the potential of its species for honey production. The life forms of bee forages showed that herbs represented the highest floristic composition, 35.1% followed by shrubs and trees 25.7% each, and climbers/lianas were 10%. The dominance of herbs is due to disturbance and the presence of canopy gaps in the forest. The dominance of herbaceous flora was also reported by Ensermu and Teshome (2008), and Yohannes et al. (2015).

Flowering season bee flora resources

Eighty-one percent of honeybee plant species were flowered from September to November, followed by March to May (10.8%) and December to February (6.8%) (Figure 4) in the Gera forest. Even though many honeybee plant species are flowered from September to November, monofloral honeys were harvested from December to February and March to May in the Gera forest. This is because 72.5% percent of flowered honeybee plant species from September to November was provided pollen for honeybees. Whereas, the majority of flowered honeybee plant species from March to May and December to February were provided nectar 56.25% and 50%, respectively (Figure 4). Pollen is used to increase the population of the bee colony, while nectar is used for honey production. Thus, the number of nectar sources is very important to produce honey.

The presence of a higher number of flowering herbaceous plant species from September to November is due to the availability of moisture following the main rainy season, which lasts from June to August. This is in agreement with a study conducted by Tura and Admassu (2018) in the Guji zone of the Oromia region indicated that herbaceous honeybee forage species were the dominant honey source plants from September to November. On the other hand, the second flowering period occurs after a small rainy season, which starts from March to May, in which the majority of honey source plants were trees and shrubs in comparison to herbaceous. For example, the tree species such as S. abyssinica, Syzygium guineense, C. macrostachyus and Eucalyptus spp. are flowered in this season (Tura and Admassu 2018). Admassu et al. (2014b) also stated that S. abyssinica, Syzygium guineense and C. macrostachyus are the most important honey-producing trees and flowers from April to March to April and hence the major honey flow period in southwest parts of Ethiopia occurred during March-June. The lower number of flowering plants was observed from June to August, which is the main rainy season throughout the country and plants tend to produce more vegetative biomass rather than producing flowers and the high scarcity of honeybee forage was observed in July to mid of August (Tura and Admassu 2018). This is in agreement with a similar study in central parts of Ethiopia (Debissa and Admassu 2009) reported that during the rainy season, low temperatures possibly inhibit flower production.

Figure 3. Pollen pictures of some major bee flora that provide monofloral honeys in Gera forest, Ethiopia. A. Croton macrostachysyus, B. Schefflera abyssinica, C. Vernonia amygdalina, D. Coffea arabica
| Family             | Plant species               | Local name (A/Oromo) | Habit | Flowering period | Rewards       |
|--------------------|-----------------------------|----------------------|-------|------------------|---------------|
| Acanthaceae        | Acanthopyle etho-germanica  | Gosa dergu           | Herb  | Sept-Nov         | Nectar & Pollen |
| Acanthaceae        | Acanthus eminens            | Korat Boye           | Herb  | Sept-Nov         | Nectar        |
| Acanthaceae        | Hypoestes triflora          | Dargu                | Herb  | Sept-Oct         | Pollen        |
| Acanthaceae        | Isoglossa somaleensis       | Gosa dergu           | Herb  | Sept-Nov         | Nectar & Pollen |
| Acanthaceae        | Justicia schimperiana       | Dumuga               | Climber | Sept-Nov     | Nectar & Pollen |
| Acanthaceae        | Acanthaceae aspera          | Maxunge              | Herb  | Sept-Dec        | Pollen        |
| Acanthaceae        | ilex mitis                  | Hangadhi             | Tree   | Sept-Oct        | Pollen        |
| Araliaceae         | Polycasas fulva             | Tul’a                | Tree   | Sept–Nov        | Nectar & Pollen |
| Araliaceae         | Schefflera abyssinca        | Gatama               | Tree   | March–Apr       | Nectar        |
| Araliaceae         | Phoenix reclinata           | Zambula              | Tree   | Sept-Nov        | Pollen        |
| Asclepiadaceae     | Periploca linearfolia       | Borino               | Climber | Sept-Nov    | Pollen        |
| Asteraceae         | Acmena caulithirna          | Yemidir berber       | Herb   | Sept-Nov        | Pollen        |
| Asteraceae         | Ageratum conyzoides         | Introduced           | Herb   | Sept-De         | Pollen        |
| Asteraceae         | Aspilia mosambicensis       | Arbi                 | Herb   | Sept-Nov        | Pollen        |
| Asteraceae         | Bidens preinitaria          | Kello                | Herb   | Sept-Nov        | Pollen        |
| Asteraceae         | Bothriacine schimperwi      | Shitto (Kafficho)    | Herb   | Sept-Dec        | Pollen        |
| Asteraceae         | Circium schimperi           | Kore Harre           | Herb   | Sept-Oct        | Pollen        |
| Asteraceae         | Galusoga quadriradiata      | Abbadebo             | Herb   | Sept-Oct        | Pollen        |
| Asteraceae         | Guizotia scabra             | Tufo                 | Herb   | Sept-Nov        | Nectar & Pollen |
| Asteraceae         | Mikaniopsis clematoide       | Kattisa              | Climber | Sept-Nov    | Pollen        |
| Asteraceae         | Solanecio gigas             | Nobe (Kafficho)      | Herb   | Sept-Nov        | Pollen        |
| Asteraceae         | Vernonia amygdalina         | Ebicha               | Shrub  | Dec-Jan         | Nectar & Pollen |
| Asteraceae         | Vernonia auricilfera        | Reji                 | Shrub  | Dec-Jan         | Nectar & Pollen |
| Basellaceae        | Basella alba                | Lebo                 | Climber | Sept-Oct    | Pollen        |
| Boraginaceae       | Cordia africana             | Vadessa              | Tree   | Sept-Nov        | Nectar & Pollen |
| Boraginaceae       | Ehretia cymosa              | Ulaga                | Shrub  | Sept-Nov        | Nectar & Pollen |
| Brassicaceae       | Brassica carinata           | Ratu                 | Herb   | Sept-Oct        | Pollen        |
| Combretaceae       | Combretum paniculatum       | Begge                | Climber | Sept-Nov   | Pollen        |
| Draecanaceae       | Draecena afromontana        | Emmo (Kafficho)      | Shrub  | Sept-Nov        | Nectar & Pollen |
| Euphorbiaceae      | Croton macrostachys         | Bakkanni             | Tree   | April-Jun       | Nectar & Pollen |
| Fabaceae           | Albizia gummifera           | Mukarba              | Tree   | Sept-Oct        | Pollen        |
| Fabaceae           | Desmodium repandum         | Silver leaf          | Herb   | Sept-Nov        | Nectar & Pollen |
| Fabaceae           | Glycine wightii             | Guiera Hanuta        | Climber | Sept-Nov   | Pollen        |
| Fabaceae           | Milletia ferruginea         | Birbira              | Tree   | Sept-Nov        | Nectar & Pollen |
| Hypericaceae       | Hypericum revolutum         | Garamba              | Shrub  | Sept-Oct        | Nectar        |
| Iccinaceae         | Apodytes dimidiata          | Chalalaka            | Tree   | Sept-Nov        | Nectar & Pollen |
| Lamiacae           | Achyropernum schimperi      | Bala dullahsa        | Herb   | Sept-Nov        | Pollen        |
| Lamiacae           | Plecanthus garckeana        | Gogoro               | Herb   | Sept-Nov        | Nectar & Pollen |
| Lamiacae           | Plecanthus punctatus        | Motijo (Kafficho)    | Herb   | Sept-Nov        | Nectar & Pollen |
| Lamiacae           | Psycnostachys eminii        | Ashoual (Hadiyaa)    | Herb   | Sept-Nov        | Nectar & Pollen |
| Lamiacae           | Salvia latifolia            | Sokoksia             | Herb   | Sept-Oct        | Pollen        |
| Lamiacae           | Saturea paradoxa            | Tseedama             | Herb   | Sept-Oct        | Nectar & Pollen |
| Loganiaceae        | Buddelia polystachya       | Anfara               | Shrub  | Sept-Oct        | Nectar & Pollen |
| Loganiaceae        | Nuxia congesta              | Irba                 | Shrub  | Sept-Nov        | Nectar & Pollen |
| Luaraceae          | Persea americana            | Avalcado             | Tree   | Sept-Nov        | Pollen        |
| Meliacae           | Ekebergia capensis          | Sombo                | Tree   | Jan-Feb         | Nectar & Pollen |
| Meliaceae          | Bersama abyssinica          | Loka                  | Tree   | Sept-Nov        | Nectar & Pollen |
| Myrsinaceae        | Maesa lanceolata            | Abayyi               | Shrub  | Sept-Oct        | Pollen        |
| Myrtaceae          | Eucalyptus globulus         | Bargamo adi          | Tree   | Mar-April       | Nectar & Pollen |
| Myrtaceae          | Syzygium guineense          | Badessa              | Tree   | Mar             | Nectar & Pollen |
| Oleaceae           | Olea capensis               | Gagama               | Shrub  | April-May       | Pollen        |
| Oleaceae           | Olea welwitchi              | Gosa Ejersa          | Tree   | April-May       | Nectar & Pollen |
| Phytolaccaea       | Phytolacca dodocandra       | Andode               | Climber | Sept-Nov   | Pollen        |
| Piperae            | Piper capense               | Turfo                | shrub  | Sept-Nov        | Pollen        |
| Pouaceae           | Andropogon australis        | Ballami              | Herb   | Sept-Oct        | Pollen        |
| Ranunculaceae      | Clematis sumisima           | Hilda fiti           | Climber | Sept-Dec    | Pollen        |
| Ranunculaceae      | Ranunculus multiflora       | Hogio (Kafficho)     | Herb   | Sept-Nov        | Pollen        |
| Rhamnaceae         | Gouania longispicata        | -                    | Climber | Sept-Nov    | Pollen        |
| Rhamnaceae         | Rhamnus prinoides           | Gesho                | Herb   | Sept-Nov        | Pollen        |
| Rosaceae           | Phlox africana              | Homba Gura           | Tree   | Sept-Nov        | Nectar & Pollen |
| Rosaceae           | Rubus idaei                 | Gora                 | Climber | Sept-Oct    | Pollen        |
| Rubieae            | Coffea arabica              | Buna                 | Shrub  | March           | Nectar & Pollen |
| Rubieae            | Galiphea saxifraga          | Didol(Kef)           | Shrub  | Sept-Nov        | Nectar        |
| Rutaceae           | Clusia anisata              | Ulumaya              | Shrub  | Sept-Dec        | Pollen & nectar |
| Rutaceae           | Vipris dinelli              | Hadhessa             | Shrub  | Dec–Jan         | Pollen & nectar |
| Sapindaceae        | Allopolythys abyssinicus     | Sarara               | Tree   | Sept-Oct        | Pollen        |
| Sapotaceae         | Pouteria officilifriderici  | Keraro               | Tree   | April-May       | Nectar        |
| Simaroumbaceae     | Brueca antidysenterica      | Nukesho (Kafficho)   | Shrub  | Sept-Oct        | Pollen & Nectar |
| Solanaceae         | Brugmansia suaveolens       | Ababo Turba          | Shrub  | Dec–Jan         | Pollen & Nectar |
| Smilacaceae        | Dombeya torrida             | Dowala               | Tree   | Sept-Nov        | Pollen & Nectar |
| Tiliaeae            | Grewia ferruginea           | Haroressa            | shrub  | Sept-Nov        | Pollen & Nectar |
| Ulmaceae           | Celtis africana             | Amalakaa             | shrub  | Sept-Nov        | Pollen & Nectar |
| Verbenaceae        | Premna schimperia           | Urgessa              | Shrub  | Sept-Oct        | Pollen & Nectar |
| Zizabereae         | Afromonum corrorima         | Korrorima            | Herb   | Sept-Nov        | Pollen & Nectar |
In conclusion, from the identified bee forage plants, four plant species were produced monofloral honey due to their abundance and high nectar yielding potential of the species in the Gera forest. These are *S. abyssinica*, *C. arabica*, *V. amygdalina* and *C. macrostachyus*. Majority flowered bee forage plants were used for colony maintenance during October and November. On the other hand, at the end of December and start of January *Vernonia* honey was harvested; at the end of February and start of March Coffee honey was harvested; in mid-April or beginning May *Schefflera* honey was harvested; and at the start of June *Croton* honey was harvested. July and August were identified as dearth period due to heavy rain. Generally, the Gera forest has a high potential for honey production. Therefore, the beekeepers should follow the flowering calendar of *S. abyssinica*, *C. arabica*, *V. amygdalina* and *C. macrostachyus* to exploit the potential of the forest for honey production. Furthermore, market promotion for monofloral honeys of the area should be made as an incentive for the beekeepers to sell honey with premium prices and branding and labeling of honey of the area.

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Figure 4. Percentage of flowered honeybee plant species in different major four seasons and food sources in Gera forest.