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Diversity, floral phenology, and socio-economic importance of melliferous plants in Eastern Ethiopia

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Abstract. *Fassil A, Habtamu T, Tahir M, Terefe T. 2022. Diversity, floral phenology, and socio-economic importance of melliferous plants in Eastern Ethiopia. Nusantara Bioscience 14: 172-181.* Beekeeping is a supply of extra money and financial gain for many thousands of farmer beekeepers in Ethiopia and plays a big role in preserving natural resources. Honeybees and flowering plants have co-evolved in their special symbiotic relationship. Bee plant types and their flowering duration differ from one place to another due to variations in topography, climate, and other cultural and farming practices. This study investigated and documented the diversity and floral phenology of honeybee plants in Doba, Gemechis, and Mi'eso Districts, Oromia National Regional State, Eastern Ethiopia, from January 2019 to July 2021. Ethnobotanical data were collected to reveal the diversity of melliferous plants, practices, and communities' attitudes about honey production and melliferous plant conservation. A total of 422 respondents participated through semi-structured interviews, focus group discussions, and field walks for socio-economic data collection. Descriptive statistics such as frequencies, ranking, and scores were used and presented with tables and figures to analyze ethnobotanical data. A total of 120 melliferous plant species were distributed under 108 genera and 55 families, of which 70 plants were found in the Gemechis District, followed by Doba and Mi'eso Districts with 47 and 42 plants each, respectively. Sorenson's Similarity Index values showed the wide-ranging melliferous plant species distribution patterns in the three districts with 50.4 (between Doba and Mi'eso), 37.5 (between Doba and Gemechis), and 15.3 (between Gemechis and Mi'eso) species overlaps. Fabaceae and Asteraceae contribute a significant number of species, with 12 (10 %) and 9 (7.5 %) melliferous plants, respectively. Local communities have a good awareness of the seasonal availability of melliferous plants, indicating adequate supply (June to early December) and critical shortage (November to early May) of melliferous plant resources favoring strong and weak colony strength, respectively. Lack of nutrition, improper management practices, honey bee predators, and lack of beekeeping knowledge and equipment were the most important constraints deleteriously influencing the honey quality and amount in the study area. The shortage of pollen and nectar flow during the dearth periods (January to March) needs interventions like hive migration and bee floral plantations. Hence, there is an urgent need for intervention through awareness creation, campaign-based melliferous plant plantations, and technology transfers.

Keywords: Ethiopia, floral phenology, honey production constraints, melliferous plant

INTRODUCTION

Beekeeping is a floral-based industry where honey bees entirely depend on flowering plants (Olana and Demrew 2019) and vice versa for their mutual benefit of pollination and provision of food in the form of pollen and nectar, respectively (Urbanowicz et al. 2020; Khalifa et al. 2021). Reproduction, productivity, and diversification successes of flowering plants are attributed to honey bees' behavior and practices of varying vegetarian diets, flower-visiting habits, hairy bodies that readily pick up pollen grains, and visit many flowers of the same species during a single trip (Bhalchandra et al. 2014). The implication is that honey bees greatly subsidize ecosystem conservation and agricultural production while they produce important products such as honey and wax (FAO 2009; Minja and Nkumilwa 2016).

Beekeeping in Ethiopia is a longstanding, quick, off-farm, environmentally friendly, and major income-generating agricultural activity, providing diverse income and employment opportunities (Sahle et al. 2018; Olana and Demrew 2019). Annual honey production in the country was estimated at 43,373 metric tons, sharing about 23.5% and 2.35% of Africa's and the world's honey production, respectively (Sahle et al. 2018). These blessings ranked Ethiopia the leader in Africa and the ninth in the world in honey production and stand first in Africa and third in the world in beeswax production (Legesse 2014).

Agro-ecology-based management of honey bees and their beehives during short or long dearth periods (Teferi 2018) and clear awareness of the effects of floral composition on honey bee food stores (Donkersley 2017) are vital, among others, for efficient honey productivity. By the same token, local beekeepers' perception and knowledge of identifying the important melliferous plant and their flowering patterns during the dry and rainy seasons greatly impact the stable production of quality honey (Novac 2017; Coh-Martínez et al. 2019). Some ready reckoner documentation of melliferous plant type, density, flowering period, and quality of melliferous plants to their nectar and pollen resource potentials help beekeepers of that particular area to start beekeeping (Harugade and Chaphalkar 2013). Development of a bee calendar based on the melliferous plant blooming period is a basic decision-making tool for beekeepers (Novac 2017), if or whether the supply of pollen substitute (Rachna et al. 2011; Pande and Karnatak 2013; Pande and Karnatak 2014), nectar supplement (Pande and Karnatak 2013; Pande et al. 2015) and/or migration of beekeeping is required.

A considerable number of previous studies conducted in Ethiopia on the melliferous plant were identification, floral establishment and honey harvesting seasons (Kebede and Samuel 2016; Tadele et al. 2016; Degaga 2017), status and production systems (Abebe et al. 2015; Tadele et al. 2016; Teferi 2018; Lango and Lomba 2020), working knowledge and perception of the community on beekeeping practices (Berhe et al. 2016; Tulu et al. 2020), trends, opportunities and challenges of honey production (Mohammed et al. 2018; Arega et al. 2020) among others. That successively needs the correct identification of honey bee plants and association with the floral calendar.

Generally, beekeeping activity in West Hararghe Zone, and Gemechis District, particularly, is relatively marginalized compared to other agricultural sub-sectors (Dawud et al. 2020). This study investigates common melliferous plants, their seasonal availability, farmers' perception and practices on honey production, and management activities in Doba, Gemechis, and Mi'eso Districts, Eastern Ethiopia. This study is expected to answer the following three questions. (i) Do Doba, Gemechis, and Mi'eso Districts have adequate melliferous plants to support sustainable honey production? (ii) What are the threats encountered in honeybee production systems in the study area? (iii) Is the floral calendar informative for the seasonal availability of honeybee sources?

MATERIALS AND METHODS

Study area

Doba, Gemechis, and Meiso Districts are found in West Hararghe Zone, Eastern Ethiopia. Doba District is located at 9˚10′0″-9˚30′0″N and 40˚55′0″E-41˚16′0″E, with elevations ranging from 1,149-2,773 m.a.s.l., Gemechis District is located at 8˚40′0″-9˚04′0″N and 4˚50′0″-41˚12′0″E, with elevations ranging from 1,300-3,017 m.a.s.l., whereas Mi'eso is geographically found at 8˚48′12″-9˚19′52″N and 40˚9′30.1″-40˚56′44″E, with elevations ranging from 1,107-1,523 m.a.s.l., Eastern Ethiopia (Figure 1).

Study design

A community-based cross-sectional study was conducted from January 2019 to July 2021in Doba, Gemechis, and Mi'eso Districts following (Berhe et al. 2016). Socio-economic data, including informant characteristics, honey production management constraints, and perception of the local community on seasonal availability of melliferous plants, were collected using semi-structured questionnaires and group discussions following Coh-Martínez et al. (2019). Questions on the seasonal availability of honey plants and honey production management were addressed to hive owners in the study area. A stratified sampling technique was employed to select the three districts based on resource availability, agroecology, and environmental variations (Binford et al. 2004). In addition, field surveys were conducted on neighboring natural forest areas and community home gardens to portray the pollen and nectar potentials of plants. Quni Forest from Gemechis District, Ades Forest from Doba District, and Asebot Forest from Mi'eso District were purposively selected for the same purpose.

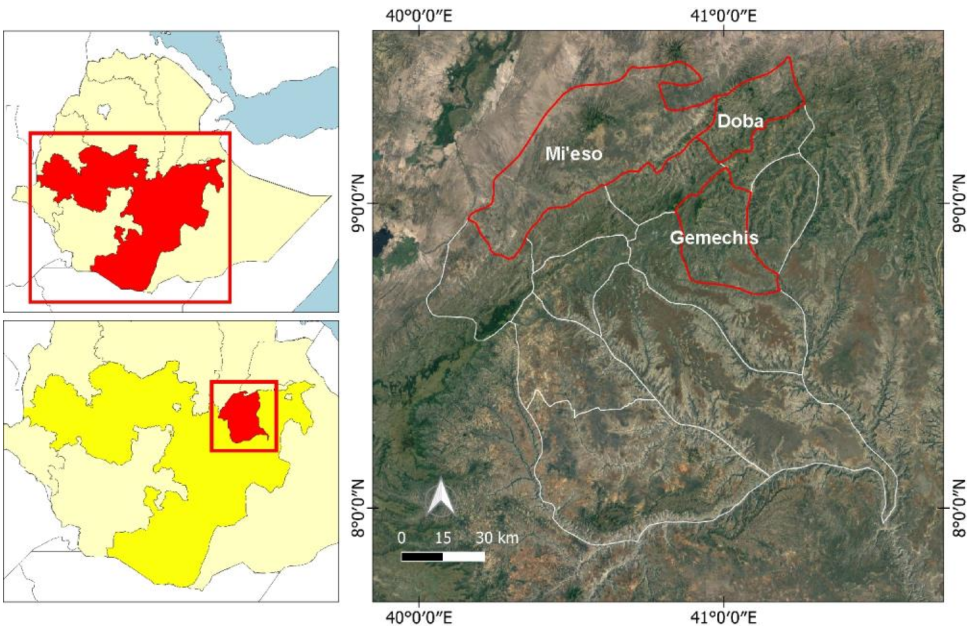

Figure 1. Map of Doba, Gemechis, and Mi'eso District in Ethiopia

Sample size and informant selection

The total sample size was determined following (Berhe et al. 2016) and using an assumption of a 95% Confidence Level (CL), 0.05 margin of error, 50% proportion, and 10% non-respondent rate. The sample size was determined using the following formula:

$$n = (Z\alpha/2)2 * P(1 - P)/W2$$

Where n is the sample size, W is the margin of error, and P is the population proportion.

Thus, 422 household sample sizes were proportionally allocated to each district (Doba, n= 126; Gemechis, n= 173; Mi'eso, n= 123) using the single population proportion formula following (Berhe et al. 2016).

Vegetation and field surveys

To portray the real experiences of the local communities on beekeeping practices, assess the challenges and constraints they face, and substantiate the reliability of data gathered through interviews and group discussions, guided field surveys were conducted in the three districts (Cheng et al. 2020). Plant specimen collection, processing, and identification were done in the field by allowing the involvement of elderly community members for vernacular name identification and specimen collection following (Martin 1995; Kent 2012). Before processing identification, specimens were stored in the Oda Bultum University Biology Department, Ethiopia, for referencing purposes following (Kent 2012). Our field study, including plant material collection, complied with the IUCN policy statement on research involving species at risk of extinction, the convention on the trade in endangered species of wild fauna and flora, and other relevant institutional and national guidelines and legislation.

Data collection instruments

Both qualitative and quantitative data collection approaches were employed to collect relevant data. Field surveys, focus group discussions (FGD), and semi-structured questionnaires were used to collect data from study participants. The semi-structured questionnaire included the following main questions, among others, i.e., (i) What are the major melliferous plants found in your locality? In which month/s do they flower? (ii) Which proper bee management practices do you prefer to do? (iii) What type of beehive do you use for honey production? (iv) In which seasons do you think the scarcity of bee forages happened? (v) In which season do colony performance become high? (vi) What are the main constraints in honey production systems?

Data analysis

Vegetation data analysis

Sorenson's similarity index was used to analyze the relative occurrence of melliferous plants in the three districts and its implication for honey productivity. Plant species were grouped into four plant habits: trees, shrubs, lianas, and herbs.

Socio-economic data analysis

Data were analyzed using descriptive statistics such as mean frequency and percentage, and graphics were presented using tables and figures.

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

A total of 422 respondents were randomly selected for the socio-economic survey (Table 1). The respondents were selected from Doba (n= 126), Gemeches (n= 173), and Mi'eso (n= 123) to include the relatively higher and lower altitudinal ranges. Most of the respondents (n=92; 85.18%) were males indicating males' great interest in devoting their time to honey production and management than their female relatives. Concerning the different age groups, respondents ranging from 30-49 showed the highest (44.79%), followed by people 50 years and above (28.43%). Concerning their educational status, the majority of the respondents (46.92%) were illiterates, followed by respondents who completed their basic education (22.52%), Primary school (19.19%), and Secondary school and above educational levels (11.37%), respectively.

Floral diversity

A total of 120 melliferous plants distributed under 108 genera and 55 families were identified from the three districts (Figure 2). Fabaceae contains the highest number of species (n= 12, 10%), followed by Asteraceae (n= 9, 7.5%). Euphorbiaceae, Poaceae, and Rosaceae were represented by 5 species (4.17%). Finally, Flacourtiaceae and Myrsinaceae were represented by 4 species each (3.33%). Hence, the above seven families were exclusively represented by 44 melliferous plants (36.66%). Gemechis District comprises 70 melliferous plants (58.33%), followed by Doba and Mi'eso Districts with 47 (39.17%) and 42 (35%) plant species, respectively.

Melliferous species similarity in the study districts

Our study evidenced wide-ranging melliferous plant species distribution patterns in the three districts (Table 2). Some 37.5% of species overlap was observed between Gemechis and Doba Districts. Moreover, 50.40% and 15.3% melliferous species similarities were observed between Doba and Mi'eso and Gemechis and Mi'eso Districts, respectively.

The melliferous species were distributed under 44 (36.66%) trees, 42 (35%) shrubs, 29 (24.16%) herbs, and 5 (4.16%) climber plant habits (Figure 3).

Seasonal availability of melliferous plants

Melliferous plant resource availability across the different months was recorded from group discussions and field surveys. First, results were converted into numerical values as 1 (plants blooming in that specific month) and 0 (plants that cannot bloom in that specific month). Then, the values were summed up and computed into percentages to ascribe the relative proportion of blooming melliferous plants each month for seasonal availability analysis (Figure

4). Our result evidenced nonconformity of floral resource availability across different months. For example, there was a critical shortage of bee forage in the dry season (January to March). In addition, in June, December, and April, the majority of the respondents viewed that there was also a moderate shortage of bee forage. On the other hand, there was less/mild shortage of bee forage in July and November.

Apart from a presence-absence inquiry for melliferous plant blooming, respondents were also asked to classify the 12 months of the year against the extent of floral resource availability (Figure 5). The criteria used to evaluate the different months against floral resource availability were adequate to supply of melliferous plant resources (where there is sufficient access to melliferous plant resources like pollen, nectar, and others to support the honey bee colony), less/moderate supply of melliferous plant resources (where the honey bee could support its colony but surplus production of honey is restricted), and a critical shortage of melliferous plant resources (where it become hard for the honey bee colony to collect floral resources to support the colony resulting in colony size decrement and migration). Most of the local community agreed that adequate melliferous plant resources supply was mown from late June to early December. At the same time, a critical shortage of melliferous plant resources occurred from the end of November to early May.

Table 2. Sorenson's similarity index in the study districts

No.	Study site	Sorenson's similarity index (%)		
		Gemechis	**Doba**	**Mi'eso**
1	Gemechis			15.3
2	Doba	37.5		
3	Mi'eso		50.40	

Table 1. Socio-economic status of respondents

Description	Range	Study districts		
		Doba (N = 133,939)	**Gemechis (N = 184,238)**	**Mi'eso (N = 130,709)**
Sex	Male	116	160	116
	Female	10	13	7
Age group	18-29	40	43	30
	30-49	48	82	59
	>50	38	48	34
Educational status	Illiterate	73	77	48
	Basic Education	18	43	34
	Primary School	25	29	27
	Secondary Schools and above	10	24	14
Altitudinal range		1149-2773 m.a.s.l.	1300-3017 m.a.s.l.	1107-1523 m.a.s.l.

Note: N: Inhabitants

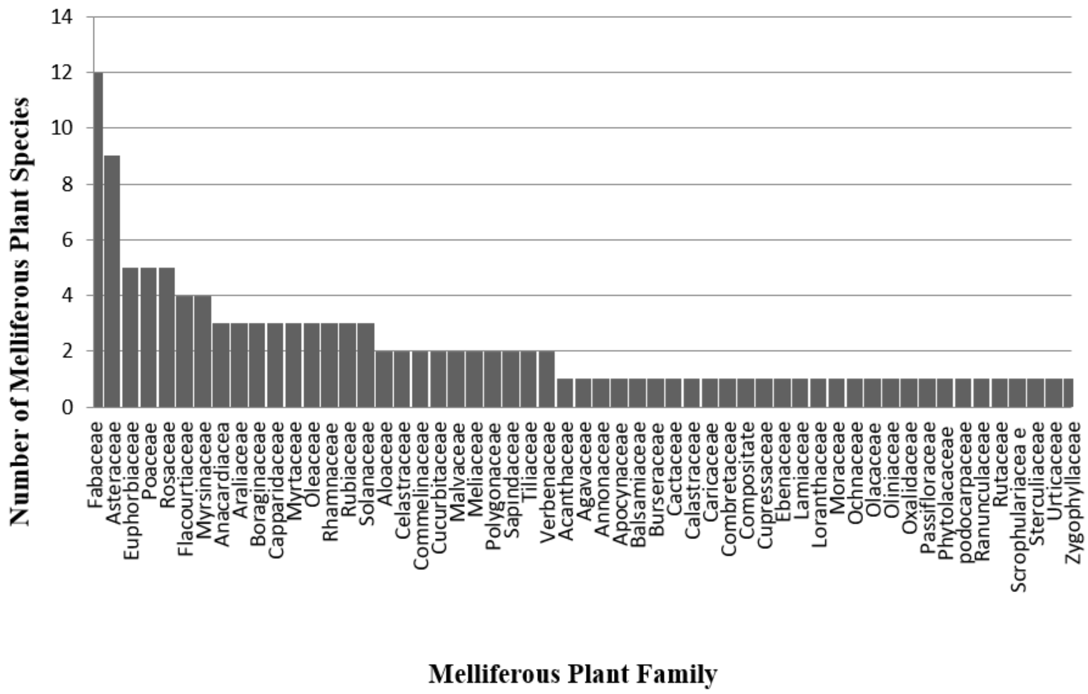

Figure 2. Distribution of melliferous plants across plant families

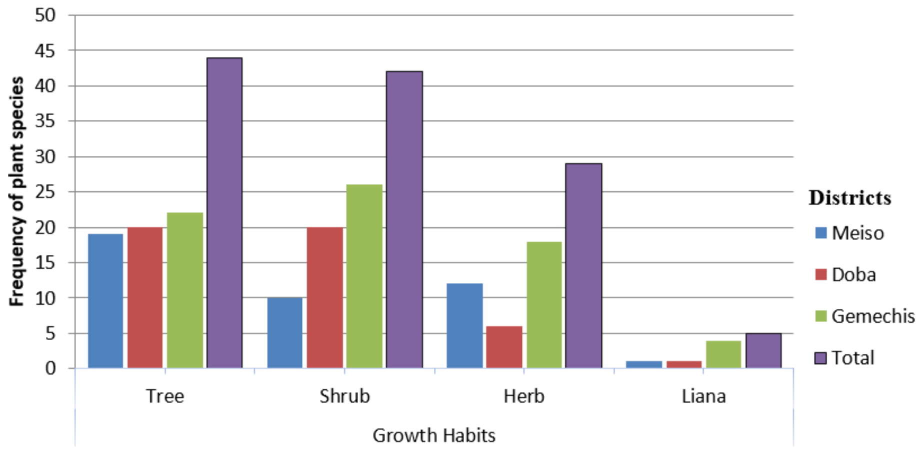

Figure 3. Plant habits of Gemechis, Doba, and Mi'eso Districts in Ethiopia

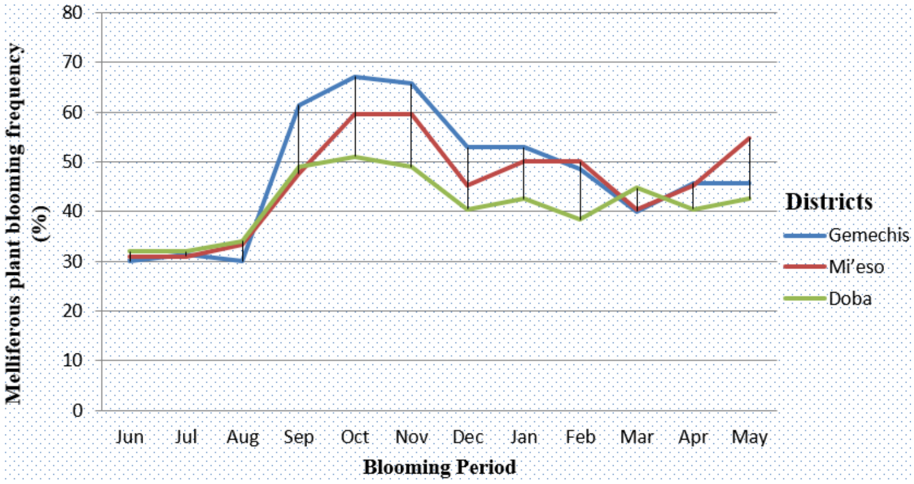

Figure 4. Floral phenology of Gemechis, Doba, and Mi'eso Districts in Ethiopia

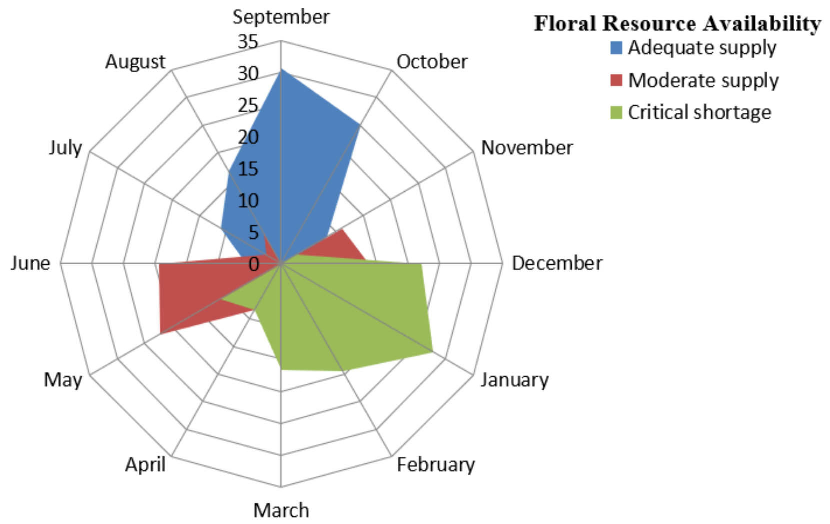

Figure 5. Annual floral resource availability in the study area

Table 3. Honey production management and constraints

No.	Constraints	Frequency	Percentage
1	Lack of nutrition, including melliferous honey plant and adequate water,	131	31.04%
2	Improper practices such as smoking, crowdedness, pesticide usage, poisonous weeds, and poor swarming management	59	13.98%
3	Honey bee predators, such as pests and birds	67	15.88%
4	Lack of Beekeeping knowledge and management skills	93	22.04%
5	Lack of equipment, such as a modern beehive and others	72	17.06%
Total		422	100%

Honey production management and constraints

A total of 422 respondents participated in this socio-economic survey to identify the honey production constraints (Table 3). The study revealed that lack of nutrition, improper management practices, honey bee predators, and lack of beekeeping knowledge and equipment were the five most important constraints deleteriously influencing the honey quality and amount in the study area. Among the above-listed constraints, lack of nutrition expressed in honey melliferous plant availability and adequate water accessibility were ranked first (31.04%) for reducing the quality and quantity of honey production by consuming honeybee products and/or killing bees themselves. Of all the 422 respondents, 93 (22.04%) cited the second honey productivity constraint: lack of beekeeping knowledge and management skills.

Farmers' perception and knowledge of the contribution of melliferous plants to honey productivity

The local community was asked whether they have experience planting honey melliferous plants to increase their honey productivity. The results showed that most respondents (61.37%) poorly understand the shortage of bee forage plants in the locality and have little experience planting melliferous honey plants for productivity. However, the rest of the respondents (39%) have a good awareness of the shortage of bee forage plants resulting in experiences of planting honey melliferous plants for honey production, which also positively impacts gross floral diversity.

Honey production practices and prospects

A total of 106 beekeepers were purposively selected for the honey productivity survey. Of these beekeepers, 70.75% preferred an exclusively traditional type of beehive; while, 19.81% had a modern type of beehive. The remaining 9.44% of beekeepers have both traditional and modern types of beehives. The honey productivity of traditional hives ranged from 2 to 10 kg/hive/year with a 4.8 kg/hive/year average yield. The honey productivity of modern hives ranged from 8-18 kg/hive/year with a mean yield of 12 kg.

Honey bee colony strength

The number of bees/colony, total comb area, and the proportion of comb that contained honey, brood, and pollen storage were the parameters used to assess the colony strength across the following season (Mushonga et al. 2019). From this study, it has been revealed that from strong to very strong, colony strength has been shown starting from the end of August to November (Figure 6).

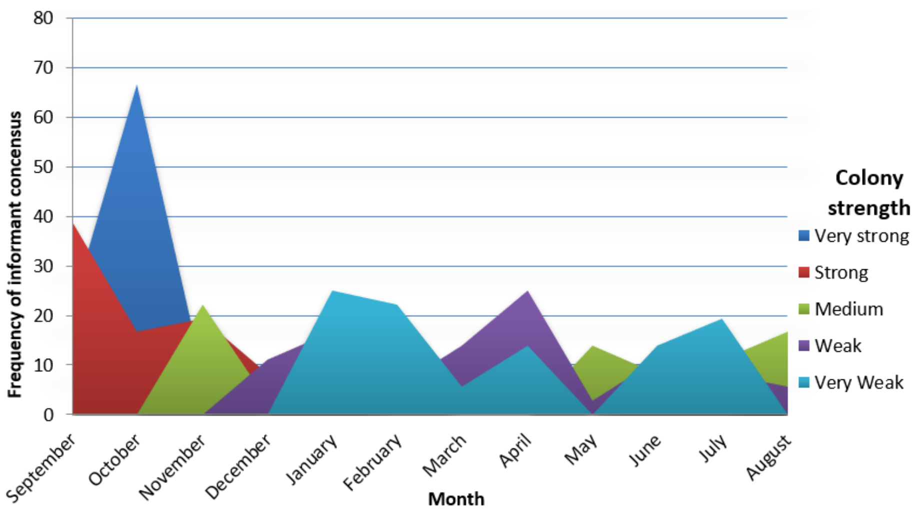

Figure 6. Months of the year in which bee colonies become strong

This intensive colony strength was observed following the winter season when floral diversity was also outsized. On the contrary, weak and very weak colony strength has been observed from mid-November to August, where either a small amount of precipitation is collected or the huge rain during July and August distracts the floral resources. Similarly, medium colony strength is also observed from May to June, apart from November. As a result, this finding revealed that the colony strength period is directly related to the floral availability time.

Discussions

Domination of male's traditional perception and practice of honey production activities in the study area showed that the perception of original male works should be done only by males (Kiptot and Franzel 2012; Tulu et al. 2020; Bihonegn and Begna 2021). The result implicated that all beekeeping interventions should include gender issues into consideration to utilize the generous women's power to enhance the productivity of the sector (Cohen and Lemma 2011; Mburu 2015; Mushonga et al. 2019). Furthermore, our study evidenced a relatively higher number of illiterate respondents than educated ones, as reported by Coh-Martínez et al. (2019) and Olana and Demrew (2019). The high illiterate proportion may challenge the honey productivity sector by hindering technology adoption and exploiting advanced training for innovative working knowledge acquisition (Coh-Martínez et al. 2019; Mulatu et al. 2021).

The floral diversity of the study area (with 120 species, 108 genera, and 55 families) is attributed to agroecological variabilities, including topography, climate, and farming practices (Teferi 2018). Our study evidenced that Fabaceae and Asteraceae have high melliferous species richness in agreement with other studies elsewhere (Dukku 2013; Olana and Demrew 2019; Khalid and Hamed 2021). According to (Venjakob et al. 2022), the families of Fabaceae and Asteraceae (both very attractive for pollinators) are particularly pronounced for their carbohydrate contents. Therefore, honey bees could benefit from many floral resources from these richest botanical families with the highest number of individuals (Filho et al. 2015). We evidenced a relatively higher procurement of plants in the Gemechis District than in the Doba and Mi'eso Districts, with 70, 47, and 42 plants, respectively. As with studies by (Fikadu et al. 2014; Sewale and Mammo 2022), the high species diversity of the Doba District was possibly ascribed to the existence of a preference for environmental/ecological gradients with which the biotic community interacts for the same token. In contrast, the low plant diversity procurements in Doba and Mi'eso Districts might be attributable to anthropogenic, topographic, and/or biological factors. Our study evidenced that the study area as a whole and/or individual study districts have higher or comparable melliferous plant diversities than the Gergera watershed in the Eastern Zone of Tigray with 52 plant species (Tekeba 2011), Zone two of the Afar region with 31 plant species (Reda et al. 2018), and Kilte Awlaelo District in Eastern Zone of Tigri with 20 plant species (Yetimwork et al. 2015).

Similar to our findings, the dominancy of melliferous plants with tree and shrub habits over herbs and climbers was documented elsewhere in the country (Dukku 2013; Kebede and Samuel 2016; Olana and Demrew 2019). The higher availability of melliferous plants with tree and shrub habits may contribute to sustainable honey production, especially at times of longer drought, as perennials often have a specific but lengthy blooming time. According to Coh-Martínez et al. (2019), the largest number of tree species in the study area is related to the knowledge of the local beekeepers, who focus primarily on the trees that bloom most of the year. However, some studies controvert lower tree and shrub melliferous plant habits than herbs and climbers (Wubie et al. 2014; Gebru et al. 2015; Addi and Bareke 2019).

Adequate knowledge of the melliferous plants and flowering times are prerequisites for establishing an apiary site (Novac 2017; Olana and Demrew 2019; Shegaw and Giorgis 2021). In addition, the temporal dynamics of plant phenology resulting in colony strength variations need proper interventions employed during those dearth periods to harvest honey sustainably and other honey bee resources (Tefera 2005; Teklu 2017; Dereje et al. 2020).

Lack of nutrition, improper management practices, honey bee predators, and lack of beekeeping knowledge and equipment are constraints hindering potential honey productivity in the study area, which is in agreement with previous studies (Sahle et al. 2018, Sebho and Baraki 2018; Dereje et al. 2020; Bihonegn and Begna 2021). Dependency on traditional honey production systems in the study area, which is also in line with the study of (Olana and Demrew 2019), may be attributed to the high financial demands of modern bee hives (Sahle et al. 2018). This study revealed that honey productivity varies with the type of beehive that the beekeepers use, which is congruent with similar studies by (Tarekegn and Ayele 2020). Similar results were also recorded in the Jimma and Illubabur Zones of the country (Welay and Tekleberhan 2017).

The colony strength and honeybee products mostly depend on the availability and type of melliferous plant next to the level of colony management practices (Bista and Shivakoti 2001; Gebru et al. 2016). The study area's major and minor honey harvesting periods are from September to December and May to June, respectively. This presence of a significant relationship between floral availability and the strength of bee colonies is also supported by the study by (Olana and Demrew 2019).

In conclusion, the present finding from the three districts (i.e., Doba, Gemechis, and Mi'eso) revealed that the study area is enriched with diversified melliferous plants for a sustainable honey production system. About 101 honey bee plant species in 88 genera and 48 families were identified from the study area. The plant species have shown variation in their distribution against the 48 families. The agroecology variation among the three study districts defines the type of flora and their floral phenology. The comprehensive floral phenology shows that there are major and minor honey harvesting seasons in the study area besides the dearth period, where there is poor floral flowering time resulting in weak colony strength and poor honey productivity. The local community has appreciably good knowledge of the types of honey melliferous plant, their floral phenology, and the management constraints on honey productivity. However, the community has poor experiences of purposeful planting of honey melliferous plants and little participation of females in the beekeeping business. Therefore, technology transfer, such as using modern beehives, awareness creation on progressive females and youths participation, and improved beekeeping activities for enhanced honey production, should improve honey productivity in the study area.

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