International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 12-05-2021, Accepted: 27-05-2021, Published: 11-06-2021
Volume 6, Issue 3, 2021, Page No. 605-610

Identification of bee floral diversity and abundance in selected districts of Arsi zone

Mulualem Ambaw[1*], Admasu Addi[2], Fekadu Seboka[1], Mezgeb Workiye[1], Amsalu Bezabh[2]
[1] Ethiopian Institute of Agricultural Research, Kulumsa Agricultural Research Center, Ethiopia
[2] Oromia Agricultural Research Institute, Holeta Bee Research Center, Holeta, Ethiopia

Abstract
Beekeeping plays a significant role s as a source of house hold income for farmer beekeepers in the country and plays a significant role in conserving the natural resources and contributes to the for food security through pollination services of honeybees. Furthermore, the success of beekeeping is depending on composition and density of bee flora. This study was conducted in three potential districts of Arsi zone. For this, three representative agro-ecologies (lowland, mid, and highland) were selected using purposive sampling procedures. A total of 90 beekeepers were selected and interviewed. Purposive sampling technique was followed to establish plot sizes of 20m x 20m, 5m x 5m, 2mx2m for tree, shrub and herb respectively. A honey pollen analysis procedure was followed to determine the botanical origin of honey. The study has revealed that 139 bee forages were identified of which Fabaceae, Asteraceae and Lamiaceae were the dominant plant families in the area. Out of the identified plant species 58.06 % are Trees, 28.05 % are shrubs and 57 % are herbs. The Shannon-Wiener diversity index (H) showed that high diversity of plant species was found in Dodota districts (2.50), Hurta (1.67) and Xiyyyo (1.72). The pollen analysis of honey indicated that Guizotia scabra, Eucalyptus spp and Hypotes forskalii were the major monofloral honeys produced from the area. It is found that the area is rich in bee forage diversity and there is great potential for production of monofloral honey. Thus conservation and rehabilitation bee plant species for beekeeping development highly recommended.

Keywords: bee forages; pollen analysis; monofloral honey; floral calendar

Introduction
Honey bee colonies required plenty of feed, pollen for brood rearing and nectar for honey production [1]. Bee colony performance as well as production of honey, wax and other hive products depends on bee forage plants. These food sources provide the nutritional requirements of the bee colonies: nectar as sources of honey provides heat and energy for honey bees and pollen provides protein, vitamins, fatty substance, and other nutrients [2]. From 250,000 plant species, 4000 plants species are available in the world to be important for bees as source of feed [3]. The diversified agro climatic conditions of the country also created suitable environmental conditions for the growth of 6000 to 7000 species of flowering plants of which most of them are bee plants [4] from those flowering plants about 800 of them are honey bee forages [5]. The unique and diversified plant species found in Ethiopia makes favorable environmental condition for the presence of large numbers of colonies and long history of beekeeping practice associated [6, 1, 7, 8]. The diversity of plant species comprises forest trees, bushes, grasses, herbs and cultivated flowering plants that are actually and potentially useful for beekeeping.

Assessing the availability of bee flora resources and establishing a floral calendar in different agro-ecological zones of Ethiopia are an important tool for beekeeping management operations including frequency of honey harvest and predicting the honey flow period of an area [9]. An agro-ecological setting and seasonal variation can affect various aspects of bee forage sources in the study zone. Thus, the availability, length of flowering, flowering phenology, nectar and pollen production of different bee plants can depend on agro-ecology of a given locality. This in turn affects the seasonal growth and productivity of bee colonies [1, 10].

Arsi zone is characterized by different agro-ecologies ranging from low lands to high lands and comprises woody and herbaceous vegetation, Acacia wood land, highland forest and various types of cultivated crops. The honey population of the zone estimated to be 76,819 colonies and 581,987kg respectively [11]. Therefore, the study was initiated to identify seasonally available bee flora and to establish flowering period and to identify botanical origin of honey of the districts.

Materials and Methods
Description of the Study Areas
The study was conducted in selected beekeeping potential districts of Arsi Zone. It is one of the 22 beekeeping potential Zones of the Oromia Regional State. It is situated between 6˚45'N to 8˚58'N latitude and 38˚32'E to 40˚50'E longitude (12). The mean annual temperature of the Zone ranges between 20˚C - 25˚C in the low land and 10˚C -15˚C in the central high land (13). It is also known for its surplus production and knows as wheat-belt of Ethiopia (14). The study districts were selected based on agro-ecology (Lowland, midland and highland).

Sampling and Data Collection
Multi-stage stratified purposive sampling design was employed to select study districts and beekeeper farmers were selected based on beekeeping potential, availability of watershed, and beekeeping experience. Accordingly, three districts from Arsi zone and from each districts three potential PAS were selected. A total of 90 beekeeper

farmers were interviewed on available bee floral species, flowering period, and major and minor honey flow season using structured and semi structured questionnaire. Moreover, focus group discussion and key informant interview also held.

Colony Establishment for Pollen Collection and Honey Production

Five [5] Zander beehives, two for honey production and three for pollen collection were placed at different sites of the study area and pollen traps having 16% pollen trapping efficiency were fitted at the entrance of beehives and pollen loads were collected for 12 months' period. The pollen samples were placed in the clean paper bag and left for 24h to dry at room temperature. After drying, they were sorted on basis of color and identified to the genus or species. To identify botanical sources of the pollen loads, a sample of ripe pollen grains were collected from mature flower buds. The fat content was washed out using ether to enhance the transparency of pollen grains. The slides were covered with a coverslip and examined under a light microscope having 400 x magnifications.

Bee Flora Inventory

Bee floral inventory were conducted based on Abebe *et al.* [15]. The abundance and frequency of bee flora were recorded using 20m x 20m, 5m x 5m, 2mx2m quadrant for tree, shrub and herb respectively within 2 km radius of apiary sites moving to north to south and west to east direction. Plant species in each quadrant were counted and frequency, density and flowering period were recorded. A total of 45 plots were sampled from study districts, of which 15 plots by district and 5 plots from each PAS. The relative abundance of botanical families was calculated as a number of plant species found in the family divided by the total number of species and multiplied by 100.

Bee Forage Richness and Diversity

The Shannon-Wiener index was calculated using the following formula.

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

Where; s is the number of species, pi is the proportion of individuals or the abundance of the ith species, and ln is the natural log, Σ is the sum of the calculations. The evenness of the species within the plant community was calculated to indicate, how the cover of the plant species within a plot is distributed. Evenness values range from 0 to 1 (Kent and Coker 1992). Equitability (evenness) is calculated using the following formula:

$$J = \frac{H'}{H'max} = \frac{H'}{\ln S}$$

Where; H': the value of the Shannon-Weiner diversity index, S: number of species in the community, ln: log base n, J: Evenness of species in sampling area, H'max: Maximum value of diversity.

Pollen Analysis of Honey

Pollen analysis was conducted following Louveax *et al. (*16). A total 30 honey samples and 10 honey samples having 0.5 kg from each district were collected during major honey flow season from October to December and transported to Holeta Bee Research Centers for pollen analysis. From each honey sample, 10 gm of honey was dissolved in 20 ml distilled water and the solution centrifuged for about 10 minutes at 2500-3000 rpm. After decanting the supernatant, the remaining residue was diluted again with 10 ml of water. After centrifuging for further 5 minutes at 2500-3000 rpm, the sediment was transferred on to a microscope slide for observation. Then glycerin jelly was added to make the pollen grains clear. After that, the pollen grains were examined under a microscope with a 400x magnification power. Percentage occurrence of pollen was used to determine their frequencies following the system adopted by Louveax *et al. (*16) for determining the major and minor honey bee plants. The proportion of pollen more than 45% were considered as major floral resource of the honey production the study areas.

Statistical Analysis

The collected data were statistically analyzed by one-way ANOVA analysis of variance and descriptive statistics using Statistical Package for the Social Sciences) (SPSS) version 20.

Results and Discussion

On the basis of the field observation and plant inventory 139 species of bee forages were identified (see the checklist) indicating the semi-arid lowlands and highlands of Arsi zone encompass higher flowering plant diversity and there is great potential for beekeeping development. Out of the identified plant species 58.06 % are Trees, 28.05 % are shrubs and 57 % were e herbs. The highest number of m*elliferous* plant species was recorded for the Asteraceae family (38.5%) followed by the Fabaceae (24.6%) and Lamiaceae (12.3%), Euphorbiaceae (7.7%), Acanthaceae (9.2%) and Poaceae (7.7%) (Figure1). The other botanical families were represented with less than 2 species. According to Tura and Admassu [9] and Tura and Admassu [17] on honey pollen analysis indicated that Fabaceae and Asteraceae the dominant bee forage families in Ethiopian honey. The frequency occurrence of the bee forages in the three districts showed that *Achyaranthes aspera*, *Achrospermum shimperi*, *Agava sisalina*, *Andropogon abyssinicus*, *Argemone mexicana*, *Clematis hirsuta* and Commelina *benghalensis* are the most wide spread and frequent species in the area (Table 1). This study is also in accordance with the finding of Admassu *et al.* [19] that *Hypoestes forskali*, *Andropogon abyssinicus*, *Commelina begahlensis* and *Brassica carinata* are widely distributed species in highlands and lowlands of Arsi zone.

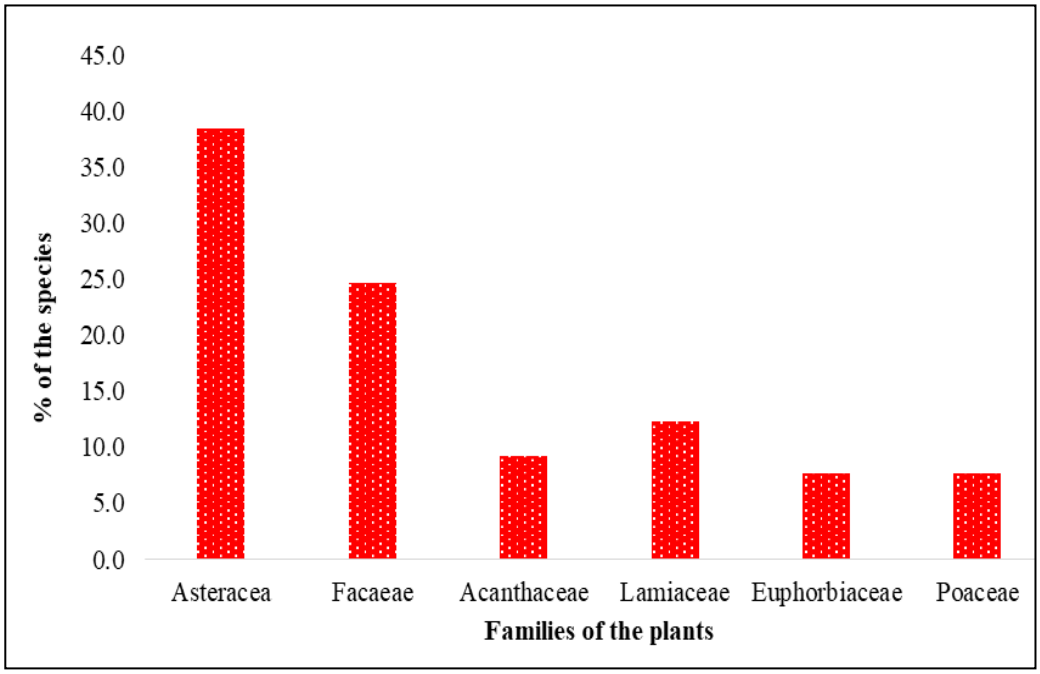

Fig 1: Number of species composition and genera in rich families in Gesha-Sayilem forest

Table 1: The frequent plant species found in sample plots

Species	Dodota	Lodhetosa	Tiyo
Acacia albida	+	-	-
Acacia seyal	+	+	-
Acacia tortolis	+	-	-
Acanthus senni	+	+	
Achyaranthes aspera	+	+	+
Acmella caulirhiza	+	+	
Achrospermum shimperi	+	+	+
Agava sisalina	+	+	+
Ageratum conzoids	+	+	-
Aloe deberana	+	-	-
Amarantus cadudata	+	-	+
Andropogon abyssinicus	+	+	+
Anethum graveolens	+	+	+
Aregemon Mexicana	+	+	+
Balanaite aeyptica	+	-	-
Bersama abyssinica	+	-	-
Bidens pilosa	+	-	-
Brassica carinata	+	+	+
Buddleja polystachya	+	+	+
Capiscum annum	+	+	+
Carica papaya	+	+	-
Caselpina decaptela	+	+	-
Casimiroa edulis	+	+	-
Caucanthus auriculatus	+	-	-
Celtis Africana	+	-	-
Citrus sinensis	+	-	-
Climantis simensis	+	+	+
commelina begahlensis	+	+	+
Commicarpus plumbagineus	+		
Hypoestes forskalii	+	+	+

Plant Diversity and Richness

The analysis of plant diversity using the Shannon Wiener diversity index revealed that Dodota has the highest species diversity followed Tiyo and Lodhetosa. The species richness also varied significantly among the district and the same pattern is observed between the study districts (Table 2). The higher diversity of the species in Dodota district is due to the fact that the area is part of the rift valley of east Africa which is known for higher species diversity.

Table 2: A diversity index of the bee forages for Arsi zone

District	H	Richness	Evenness
Lodhetosa	1.67	9.70	0.87
Tiyo	1.72	13.00	0.90
Dodota	2.50	21.14	0.90

Floral Calendar

Regarding the flowering period of the bee forages, it was observed that percent abundance of bee flora was highest with 66 % during Sept-Nov followed by 12% in Dec – Jan, 13.8% during March–May 8.2 % in July to August (Fig: 2). The presence of higher number of flowering plant species during September to November is due to availability of moisture following the main rainy season lasting from June to August which initiate flowering herbaceous flora and cultivated crops. This is in agreement with (9, 20) reported that the majority of bee plants flower after the main summer rain season June to early September. On the other hand, the second flowering period occurs after small rainy season which starts from March to April and hence the minor honey flow period occurred during April–June mainly from Eucalyptus spp in most parts of the central Ethiopia including the rift valley region of the Ethiopia (20). The lower number of flowering plants was observed during June to August which is the main rainy season throughout the country including the study area and plants tends to produce more vegetative biomass rather than producing flowers. This is in agreement with similar study in central parts of Ethiopia (21) reported that during the rainy season, low temperatures possibly inhibit and flower production.

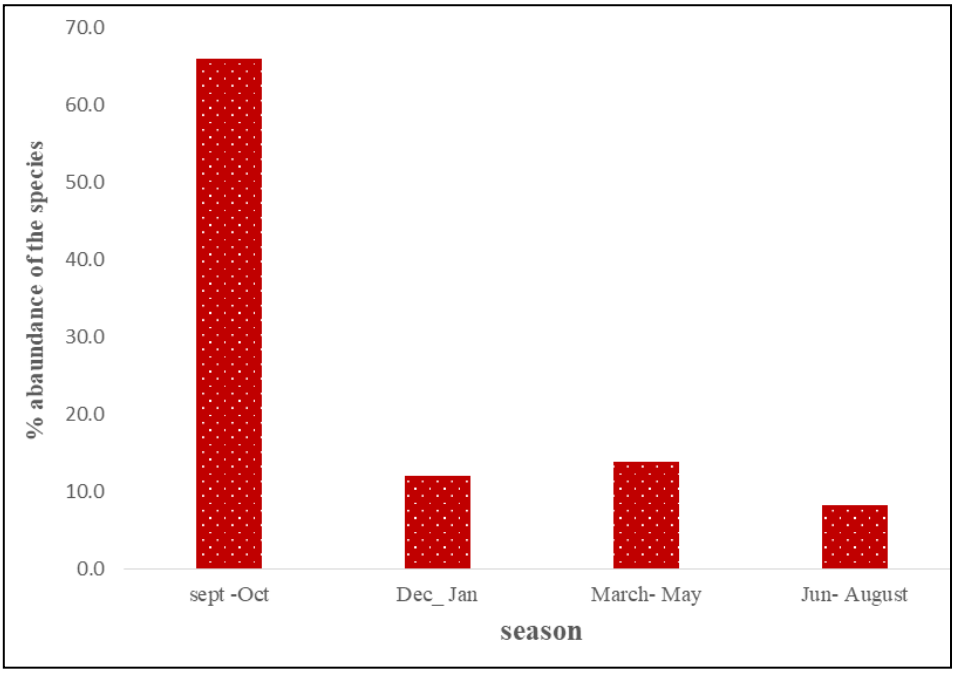

Fig 2: Abundance of bee forages in different flowering seasons

Pollen Analysis

The results of honey pollen analysis were indicated in (Table. 3). A total 46 honeys-source plants were identified from three districts. The predominant pollen types were *Guizotia scabra*, *Eucalyptus spp*, and *Hypoestes forskaolii*. The secondary pollen source plants were *Trifolium* spp., *Gallineria saxifraga*, and Ocimum spp. The diversity of important minor and minor honey source plant species were higher than predominant species and secondary pollen sources. According to this analysis three types of the monofloral honey were identified which include *Guizotia scabra Eucalyptus spp and Hypoestes forskaolii. The Guizotia scabra* monofloral honey was contributed by five plant species of which *Clausena anisata, Maytenus obsura, Gallinaria saxifraga*, Eucalyptus spp and *Syzygium guineense* and their percentage pollen frequency was indicated in (Figure 3). Similarly, the Eucalyptus mono floral honey was contributed by *Olea africana, Coffea arabica and, Acacia spp.* On the other hand, the *Hypoestes forskaolii* monofloral honey was contributed by seven species as shown in spider web. In convulsion, *Guizotia scabra, Eucalyptus* spp and *Hypoestes forskaolii* honey were identified as sources of monoclonal honeys. This indicates that there is a huge potential for the production of monoclonal honey in the Arsi zone. Since monoclonal honey has good market value and favored by consumers.

Table 3: Predominate, dominant and secondary source plants from study area.

District	Predominant pollen	Secondary pollen	Important minor pollen	Minor pollen source
	source (> 45%)	source (16-45%)	source (3-15%)	(< 3%)
Dodota	*Guizotia scabra*	*Hypoestes forskaolii*	*Acacia tortolis*	*Justicia schimperina*
	Hypoestes forskaolii		*Elesine foliccofolia*	*Rumex nervosus*
		Trifloum spp		*Bidens spp*
				Achyranthes aspera
		Ocimum spp		*Trifolium spp*
Tiyo	*Guizotia scabra*			
	Eucalyptus spp		Eucalyptus spp.	*Plantago lanceolata*
				Zea mays
				Craceocephalum spp
				Bidens spp

				caylusea abyssinica
				Justicia heterocarpa
				Brassica carinata
Lodhetosa				
	Guizotia scabra	*Galineria saxifrga*	Eucalyptus spp	Clausena anisata
			Maytenus obscura	*Trifloum* spp
				Coffea Arabica
				Phytolcca dodocandra
				Ranuclus multifidus
				Cirsium schimperi
				Unknown
				Echinops ellenbeckii
				Clematis hirsute
				Brassica carinata

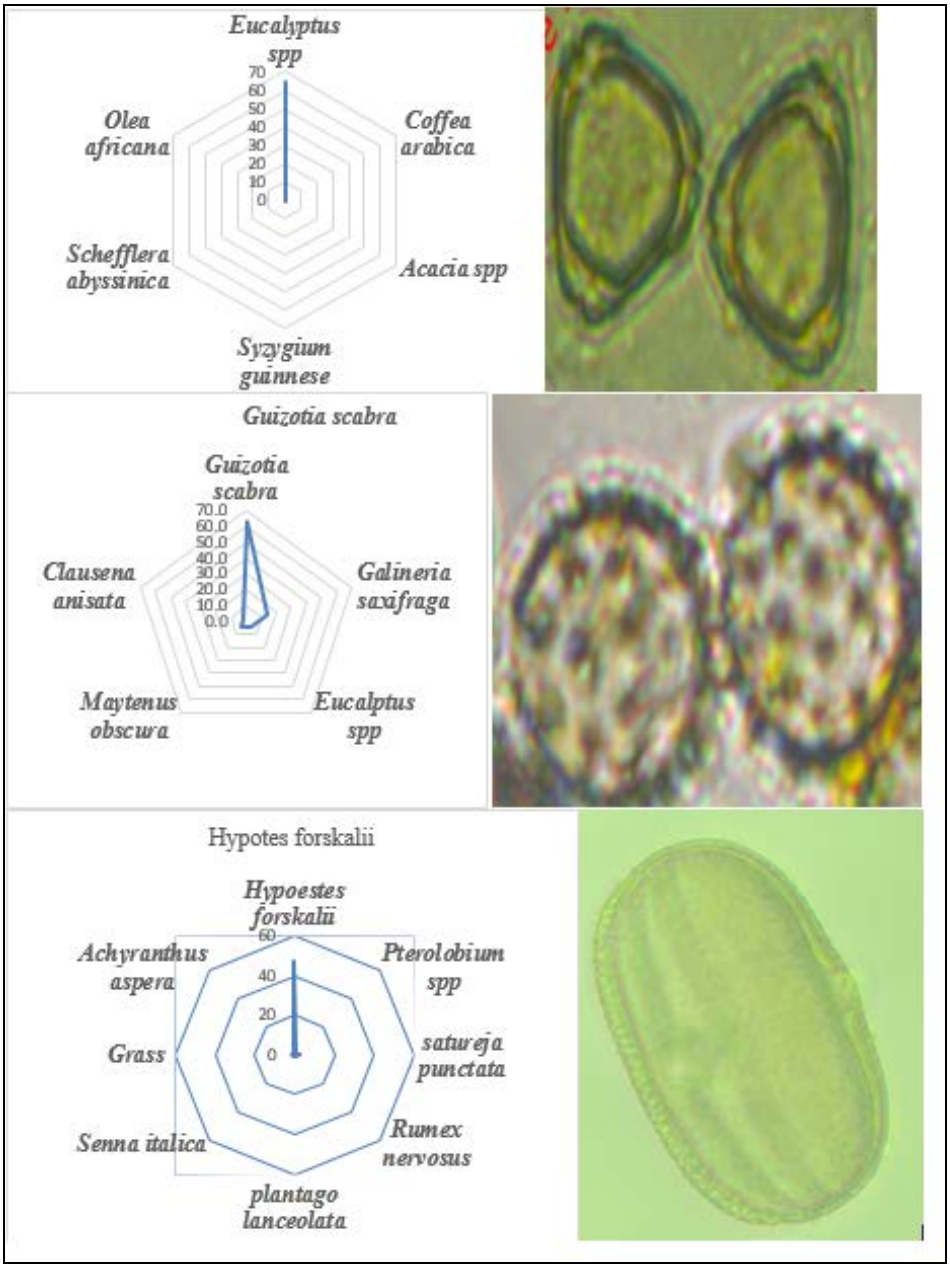

Fig 3: Spider web distribution for Monofloral honeys with their respected percent dominancy

Acknowledgments
We would like to acknowledge Holeta Agricultural Research Center and the center staffs for their support during laboratory and field work. Ethiopian Institute of Agricultural Research and Kulumsa Agricultural Research Centerare acknowledged for their financial support. We are also please to acknowledge Agricultural experts and beekeeper farmers for their cooperation and assistance during field data collection.

Availability of Data and Material
The lists of plant species

Competing Interest

No any competing interest regarding this paper

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