Citation/Atıf: Tarekegn A. Identification, characterisation, and evaluation of honey bee flora in Benishangul Gumuz regional state, Ethiopia. U. Bee J. / U. Arı D. 2025; 25 (1): 19-31. DOI: 10.31467/uluaricilik.1587466

ARAŞTIRMA MAKALESI / RESEARCH ARTICLE

IDENTIFICATION, CHARACTERISATION, AND EVALUATION OF HONEY BEE FLORA IN BENISHANGUL GUMUZ REGIONAL STATE, ETHIOPIA

Benishangul Gumuz Bölgesel Eyaleti, Etiyopya'da Bal Arısı Florasının Tanımlanması, Karakterizasyonu ve Değerlendirilmesi

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Received / Geliş:18.11.2024 Accepted / Kabul:31.01.2025 DOI: 10.31467/uluaricilik.1587466

ABSTRACT

This study aimed to identify and evaluate the major and minor bee forage sources to recommend seasonal colony management practices. Conducted in the Bambasi, Homosha, and Mao Komo districts of Benishangul Gumuz Regional State in western Ethiopia, the research involved a survey of 90 beekeepers using semi-structured questionnaires from three peasant associations per district. Honey and pollen samples were collected from established colonies in each district for melissopalynological analysis. 71 plant species were identified as forage sources for honeybees in the study area. Two primary flowering periods were observed in 2020, 2021, and 2022 G.C., corresponding to the honey harvesting seasons. During the first season, key plants included *Pterocarpus lucens, Bidens prestinaria, Glycine* species*, Guizotia abyssinica, Guizotia scabra,* and several *Bidens* species. From February to May, the main sources of pollen and nectar in the second season were woody plants such as *Cordia africana, Syzygium guineense, Turraeanthus africanus,* and *Terminalia laxiflora*. In the first honey flow season, *Guizotia scabra* and *Guizotia abyssinica* made up 62.13% of monofloral honey. In the second season, *Turraeanthus africanus* and *Syzygium guineense* contributed 48.23%. In Benishangul Gumuz, beekeepers report that food scarcity peaks during the rainy season (late July to August) and the dry season (December to January) when flowering plants are limited. Providing supplemental food and water and conducting regular inspections is important to support the bee colonies during these times. Additionally, rapid biodiversity loss from deforestation and agricultural expansion reduces available bee forage in the region.

Keywords: Bee flora, Bee forage, Honey, *Guizotia* species, Melissopalynology

ÖZ

Bu çalışma, mevsimsel koloni yönetimi uygulamalarını tavsiye etmek için ana ve küçük arı yem kaynaklarını belirlemeyi ve değerlendirmeyi amaçlamıştır. Batı Etiyopya'daki Benishangul Gumuz Bölgesel Eyaleti'nin Bambasi, Homosha ve Mao Komo ilçelerinde yürütülen araştırma, ilçe başına üç köylü derneğinden yarı yapılandırılmış anketler kullanılarak 90 arıcı ile yapılan bir anketi içermektedir. Melissopalynolojik analiz için her ilçedeki yerleşik kolonilerden bal ve polen örnekleri toplanmıştır. Çalışma alanında 71 bitki türü bal arıları için yem kaynağı olarak tanımlanmıştır. Bal hasat mevsimlerine denk gelen 2020, 2021 ve 2022 yıllarında iki ana çiçeklenme dönemi gözlemlenmiştir. İlk sezonda, kilit bitkiler şunları içeriyordu Pterocarpus lucens, Bidens prestinaria, Glycine türleri, Guizotia abyssinica, Guizotia scabra ve birkaç Bidens türü içermektedir. Şubat ayından Mayıs ayına kadar, ikinci sezonda ana polen ve nektar kaynakları Cordia africana, Syzygium guineense, Turraeanthus africanus ve Terminalia laxiflora gibi odunsu bitkilerdir. İlk bal akış sezonunda, Guizotia scabra ve Guizotia abyssinica monofloral balın %62,13'ünü oluşturmuştur. İkinci sezonda, Turraeanthus africanus ve

Syzygium guineense %48,23 oranında katkı sağlamıştır. Benishangul Gumuz'da arıcılar, çiçekli bitkilerin sınırlı olduğu yağmur mevsimi (Temmuz sonundan Ağustos'a kadar) ve kurak mevsimde (Aralık'tan Ocak'a kadar) gıda kıtlığının zirve yaptığını bildirmektedir. Bu dönemlerde arı kolonilerini desteklemek için ek gıda ve su sağlamak ve düzenli denetimler yapmak önemlidir. Ayrıca, ormansızlaşma ve tarımsal genişlemeden kaynaklanan hızlı biyoçeşitlilik kaybı, bölgedeki mevcut arı yemini azaltmaktadır.

Anahtar Kelimeler: Arı florası, Arı yemleri, Bal, Guizotia türleri, Melissopalynoloji

GENİŞLETİLMİŞ ÖZET

Amaç: Bir çiçek takvimi oluşturmak, kovan ballığı eklemek ve bal akışını tahmin etmek gibi temel faaliyetleri düzenlemek için çok önemlidir. Bu nedenle, bu çalışma etkili mevsimsel koloni yönetimi uygulamaları önermek için temel arı yemlerini tanımlamayı, karakterize etmeyi ve değerlendirmeyi amaçlamaktadır.

Gereç ve yöntem: Çalışma, Batı Etiyopya'nın Homosha, Bambasi ve Benishangul Gumuz Bölgesel Eyaleti'nin Mao Komo özel bölgelerinde gerçekleştirilmiştir. Her ilçedeki üç köylü derneği, arıcılık potansiyellerine ve agroekolojik farklılıklarına göre seçildi. 2020'den 2022'ye kadar, çiçek yoğunluğu yüksek olan çeşitli bitkiler incelenmiştir. Bal ve polen örnekleri toplamak için dokuz bölgede arı kolonileri kurulmuştur. Her sahada beş kutu kovan kurulmuştur: ikisi polen yakalama ve üçü bal örnekleme için. Bal örnekleri Kasım-Aralık ayları arasındaki büyük ve küçük akış mevsimlerinde ve Nisan ayında botanik kökenlerini belirlemek üzere laboratuvar analizi için toplanmıştır. Sonuçlar, çalışma alanında bal arıları için yem kaynağı olarak yetmiş bir bitki türünün tespit edildiğini göstermektedir. Bu türlerin yüksek çeşitliliği, arıcılık için uygun olan yağlı tohumlar, tahıllar, bakliyat ve bahçe bitkileri de dahil olmak üzere doğal olarak oluşan bitkilerden ve ekili ürünlerden kaynaklanmaktadır. Tespit edilen bitki türlerinin 44'ü (%61,98) ağaç, 12'si (%16,90) ot, 9'u (%12,67) çimen, 3'ü (%4,23) çalı, (%2,81) tırmanıcı ve 1'i (%1,41) asmadır. Çalışılan üç ilçede de bal arısı bitkileri için iki ana çiçeklenme dönemi vardı ve bu da bölgedeki iki bal hasat dönemine karşılık geliyordu. Tespit edilen arı yemi türlerinin %70'i Eylül ve Kasım ayları arasında çiçeklenmiştir. İlk bal akışı sezonunda birincil ve en değerli arı yemi bitkileri Pterocarpus lucens, *Bidens* prestinaria, *Glycine* türleri, *Guizotia abyssinica*, *Guizotia scabra* ve diğer *Bidens* türlerini içeriyordu. Buna karşılık, Şubat-Mayıs ayları arasında gerçekleşen ikinci bal akışı sezonunda, *Cordia africana, Syzygium guineense* ve *Terminalia laxiflora* gibi odunsu bitkiler ana polen ve nektar kaynakları olarak öne çıkmaktadır. Çalışma alanında bitkilerin dağılımına bakıldığında en fazla türün yayla bölgesinden toplandığı görülmektedir.

Bulgular ve sonuç: Sonuçlar, ağaç arısı yemlerinin bolluğunun, ikinci bal akışı sezonu için hayati önem taşıyan kurak mevsimde daha yüksek olduğunu göstermiştir. Polen örnekleri çalışma alanının farklı bölgelerinden toplanmıştır *Guizotia* türleri ve Terminalia laxiflora çalışma alanlarında tespit edilen başlıca polen kaynağı bal arısı bitki türleridir. *Guizotia scabra* ve *Guizotia abyssinica* monofloral bal üretimi için önemli olup, %62,13 sıklıkta gözlenmiştir. Benishangul Gumuz'da arıcılar, gıda kıtlığının en yoğun olduğu dönemlerin Temmuz sonundan Ağustos'a kadar olan yağışlı sezonda ve Aralık'tan Ocak'a kadar olan kurak sezonda gerçekleştiğini gözlemlemiştir. Belirlenen polen ve nektar kaynaklarının besin değerini değerlendirmek için araştırma yapılması gerekmektedir. Tarım alanları içinde ve çevresinde arı dostu bitkileri entegre eden tarımsal ormancılık sistemlerinin teşvik edilmesi de önemlidir.

INTRODUCTION

Ethiopia has abundant natural and cultivated flora, along with diverse agro-ecological and climatic conditions that are ideal for beekeeping (Jacobs et al. 2006). Ethiopia produces 66221.82 tons of honey and 6,000 tons of wax (CSA 2018), showcasing its significant contributions to the honey and wax industries. The honey is exceptional for its distinct flavor, aroma, and color, all of which are influenced by the floral sources and geographical origin (Belay et al. 2017). However, many beekeepers still rely on traditional methods, which are less efficient and can lead to lower honey yields and quality.

Western Ethiopia is recognized as a promising area for commercial and small-scale beekeeping due to its high vegetation density and a substantial population of honeybees (Addi and Bareke 2019). Benishangul Gumuz, one of the regional states in western Ethiopia, is particularly rich in natural resources and has favorable climatic conditions supporting beekeeping development. In this region, beekeeping is a significant income source for communities living near the forests (Abebe et al. 2016).

Success in beekeeping relies heavily on the availability and abundance of floral resources for bees (Addi et al. 2014). The development of beekeeping in any region requires a thorough understanding of the local flora, including the length of flowering periods, flowering phenology, and the nectar and pollen production of various bee plants (Wubie et al. 2014). There is a strong correlation between the seasonal cycles of honeybee colonies and the flowering calendar of bee plants (Haftom et al. 2014). This relationship can be utilized for effective seasonal management of bee colonies. It is essential to time management operations by the phenological patterns of local bee plants, as this is crucial for building up colony populations before the main nectar flow. While bees naturally increase their population when resources are abundant, beekeepers must take steps to ensure that the colony reaches its peak population size either before or during the nectar flow.

Different locations exhibit variations in plant species composition and flowering durations due to factors such as topography, climate, and cultural and agricultural practices (Reinhard and Admasu 1994). To achieve successful beekeeping, it is essential to have extensive knowledge of the types, population density, and quality of floral rewards, including nectar and pollen. The diversity of honey types produced in a specific area is influenced by the variety of nectar-producing plant availability (Silici and Gökceoglu 2007). This diversity can be identified through honey pollen analysis.

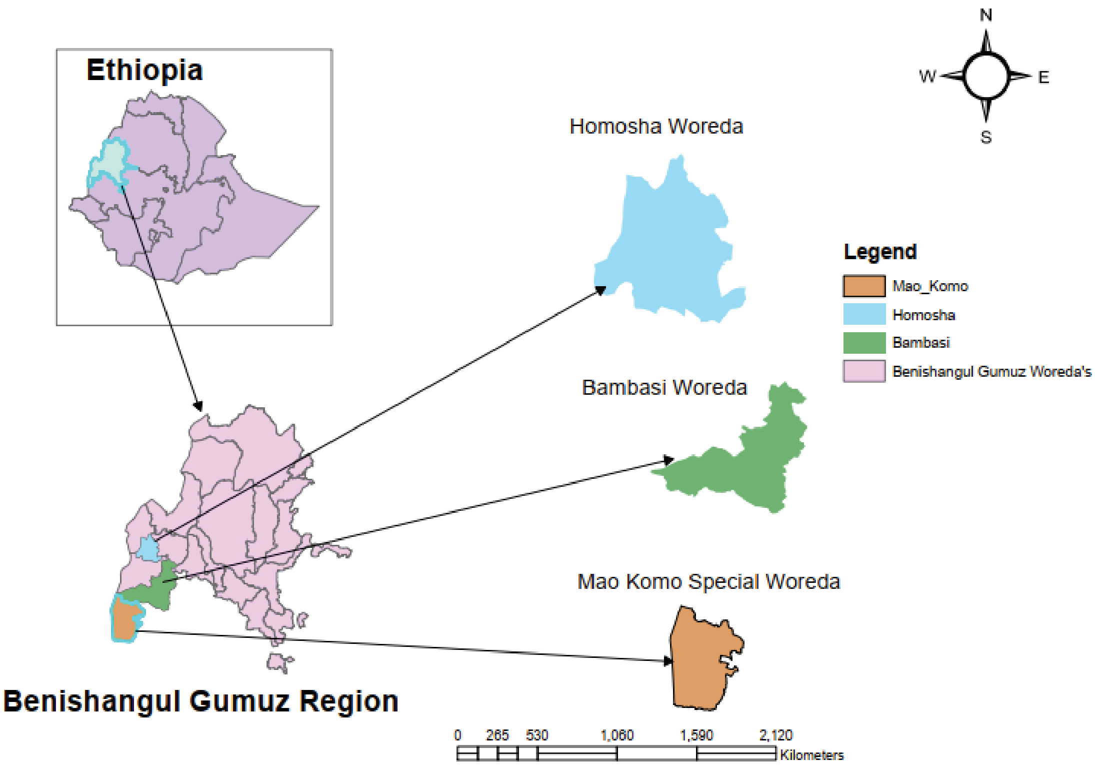
Melissopalynology is the definitive study of pollen grains found in honey (Louveaux et al., 1978). This analysis is crucial for determining the geographical and botanical origins of honey through microscopic examination of honey sediments. The study is a more reliable method than visual surveys for investigating honeybee forage, making it an essential tool for the development of regional apiculture (Begum et al. 2021). Honey can be classified as monofloral or multifloral. Monofloral honey is primarily derived from the pollen of a single plant species, while multifloral honey contains pollen from multiple species (Louveaux et al. 1978). A study conducted in southwest Ethiopia identified *Terminalia* spp., *Guizotia* spp., and *Bidens* spp. as the most important secondary pollen sources, with *Eucalyptus camaldulensis* being the predominant pollen type (Tulu et al. 2023). Furthermore, another study indicated that the leading pollen sources during the first honey harvesting season were *Guizotia* species, while *Coffea arabica* was predominant in the second harvesting season in the western Oromia region of Ethiopia (Tesfaye et al. 2023).

In Benishangul Gumuz, the assessment of bee forages is insufficient to identify high-performing plants that could enhance beekeeping practices. The major and minor bee plants identified through honey pollen analysis lack proper documentation, and their relationships to the seasonal colony management calendar are not well established. This oversight hinders the recognition of unique production opportunities, thereby limiting the potential for sustainable beekeeping that could benefit local economies. To improve honey production using the region's resources, it is essential to document economic bee forages and their flowering calendars. While creating a complete overview of all flowering plants may not be feasible, focusing on major bee forage plants and their flowering times will support effective beekeeping management. Additionally, by mapping floral resources, researchers can identify areas of high biodiversity and implement conservation measures to protect these valuable ecosystems. Establishing a floral calendar is crucial for organizing key activities, such as adding hive supers and predicting honey flow. Therefore, this study aims to identify, characterize, and evaluate key bee forages to recommend effective seasonal colony management practices.

MATERIALS and METHODS

The study was conducted in the Homosha, Bambasi, and Mao Komo special woredas of the Benishangul Gumuz Regional State in western Ethiopia, located between 9°30'N to 11°39'N latitude and 34°20'E to 36°30'E longitude. These districts represent lowland, midland, and highland agro-ecologies. Assosa, the regional capital, is 670 km west of Addis Ababa, with

Mao Komo 105 km south, Bambasi 40 km southeast, and Homosha 30 km north of Assosa (Fig. 1).
The region experiences a long uni-modal rainfall pattern (May to November), with annual precipitation ranging from 340.9 mm in 1996 to 2417.5 mm in 2000, averaging around 1146 mm. The temperatures in the area vary, with minimum average temperatures between 16.8 °C and 20.6 °C, and maximum averages ranging from 27 °C to 35.1 °C and elevation from 580 to 2731 masl (NMA 2017). The predominant vegetation consists of woodlands and shrubs, which cover 77% of the region, while grasslands and cultivated land account for 3% and 5%, respectively (AsARC 2006, unpublished).
The local farming system primarily involves mixed crop-livestock production (WBISPP 2003). The main crops grown in the area include sorghum, maize, haricot beans, soybeans, sweet potatoes, onions, mangoes, and various other fruits and vegetables. The key cash crops of the region are sesame, 'nug' (*Guizotia abyssinica*), and red pepper.



Figur 1. Map of the study area

Survey and inventory of bee forages

In each district, three peasant associations were chosen based on their potential for beekeeping and prior experience. From 2020 to 2022 G.C., a comprehensive survey was conducted to examine various plants, including trees, shrubs, grasses, crops, and weeds that exhibit high floral density. To collect primary data, semi-structured questionnaires were administered to 90 beekeepers selected from the nine peasant associations. Furthermore, secondary data was collected from district and zonal agricultural offices. Beekeepers categorise flowers into major and minor bee floras. Major bee floras were attracted a larger number of bees, while minor bee floras were visited by fewer bees and less often (Teklay 2011). This distinction was based on the quantity and frequency of bee visits to the flowers.

Participatory Rural Appraisal techniques were employed, which included focused group discussions, resource mapping, mental and social mapping, modeling, transects, and historical timelines, ranking, and scoring preferences, and observation with model beekeepers, development agents, bee technicians, and experts. These discussions aimed to identify local honeybee plants and their flowering seasons. Following these sessions, plant samples were collected for botanical identification, noting features such as leaves and flowers, with assistance from a biodiversity expert from the Assosa biodiversity office. The area's bee flora was further validated through direct observation and published reports using taxonomic keys in Books of Flora of Ethiopia and Eritrea (Hedberg 1996) and Honey Bee Flora of Ethiopia (Reinhard and Admasu 1994).

Honey bee flora cover-abundance

The occurrence of the plant species in each agro-ecologies was determined by bee flora composition and diversity in the study area. The size of the quadrate used in the cultivated land and pasture was 25 m^2 (5 m*5 m), while for closed forest area used 400 m^2 (20 m*20 m), and for homestead land 100 m^2 (10 m*10 m) quadrate in a two-kilometer radius every 0.1 km from the hive. A total of 30 plots were taken from each district, representing different agro-ecosystems. At each quadrant observations of the plant were included whether the plant was visited by honeybees, flowering period, and food source. Then cover within a quadrat determined which was occupied by the above-ground parts of each bee plant species when viewed from above. Cover abundance was estimated visually as a percentage by stratification in multiple layering of vegetation types (trees, shrubs, and herbaceous). For recording the cover-abundance determination was used Braun-Blanquet scale from r (one or few individuals with less than 1% cover of the area) to 5 (75- 100% cover of the total area irrespective of the number of individuals) (Westhoff and Van der Maarel 1973).

Honey and pollen sample collection

For honey and pollen sample collection colonies were established in selected nine sites in the study area. In each site, five honey bee colonies were established in box hives (two for pollen trapping and three for honey sampling). To determine the botanical origin of the honey in the laboratory, fresh honey samples from each site were collected at major and minor honey flow seasons from November to December and April respectively.

To collect the pollen, honeybee colonies were fitted with pollen traps with 16% pollen trapping. Pollen loads were collected twice every seven days intervals. Pollen samples were dried and sorted by colour at Assosa Agricultural Research Center Laboratory and maintained until used for analysis. The collected honey and pollen samples were brought to the Holota Bee Research Centre Laboratory, using sterile glass cup honey containers for Melissopalynological analysis.

Pollen extraction from honey was carried out according to the method described by Louveaux et al. (1978). For this, 10 grams of honey was dissolved in 20 ml of warm distilled water and was stored at a temperature range of 20-40°C. The solution was centrifuged at 3800 rpm for 10 minutes and decanted the supernatant. Again, 20 ml of distilled water was added to completely dissolve the remaining sugar crystals and again centrifuged at 3800 rpm for 5 minutes and the supernatant was removed. The remaining precipitate was spread evenly on a microscope slide and the sample was exposed to air dry. Finally, one drop of glycerin jelly was added to the coverslip and examined under the light microscope (Zeiss AxioVert, Mg. Power 40*x*), and the morphological structure of selected pollen pictures were taken from each slide. The source of dominant pollen plants was then identified using reference slides and a pollen atlas (Adgaba 2007). Observation of fungal spores, soot particles, fine granular mass, and mineral particles were also included in the analysis.

The nomenclature of honey based on the frequency classes was determined by samples of percentage calculation, 500-1000 pollen grains had to be counted and the following terms have been adopted. The types of pollen were allocated to one of four frequency classes for nectar source plants: predominant pollen (>45%); accompanying pollen (16%-45%); important isolated pollen (4%-15%); and isolated pollen (3%) (Louveaux et al 1978). The percentages of pollen types in each honey sample were calculated based on the total number of different kinds of pollen grains counted for each honey sample. Then the honeys with predominant pollen types were considered as monofloral and if there was no predominant pollen then this kind of honey was classified as multifloral.

Richness and diversity of bee forage plants

The Shannon-Wiener diversity index, species richness, and Shannon's evenness were used to determine the diversity of bee forage plant species. Shannon index (H') =Ʃ (pi*lnpi), where H' = Shannon index, pi= proportion of individual species, and Ln= log base n; Evenness (J) = H'/ H'max = H'/INS, where H' =Shannon diversity index, H'max = lns where S was the number of species, Ln = logbase.

Data analysis

Descriptive statistics, including mean, frequency, percentage, and standard deviation, were used to summarize primary and secondary data. Secondary sources were obtained from the Agricultural office and research center around the study area. SPSS (version 23) was used to analyze the data.

RESULTS

Honey bee forages

Seventy-one plant species were identified as forage sources for honeybees in the study area. The high diversity of these species results from naturally occurring plants and cultivated crops, including oilseeds, cereals, pulses, and horticultural crops, all suitable for beekeeping. Among the plant species identified, 44 (61.98%) were trees, 12 (16.90%) were herbs, 9 (12.67%) were grasses, 3 (4.23%) were shrubs, (2.81%) were climbers, and 1 (1.41%) was a vine (Table 1). In the study area, fifteen tree species were identified as having a high abundance among bee forage species. The major bee forage species during the first honey harvesting season (mid-November) included *Pterocarpus lucens, Acacia hecatophylla, Cordia africana, Croton macrostachyus, Ficus sycomorus,* and *Lannea welwitschii*, all of which were particularly important for honeybees. During the second honey flow season (April) beekeepers identified *Syzygium guineense* and *Terminalia laxiflora* as the most important honeybee plants. Notably, the beekeepers emphasized that *Syzygium guineense* and *Terminalia laxiflora* were major sources of forages for honeybees and play a critical role in honey production due to their abundant flowers, which provide excellent nutrition for the bees.

The beekeepers identified several key herbaceous and grass species that were frequently visited by bees for pollen and nectar. Among these abundant species, compared to other herbs and grasses were *Bidens prestinaria, Guizotia abyssinica, Guizotia scabra, Sorghum bicolor,* and *Bidens pilosa*. *Bidens* species*, Guizotia scabra,* and *Plantago larceolata* were found in both forested and cultivated areas, playing a crucial role during the honey flow season (Table 1).

Table 1: Honeybee forage species, identified based on survey and field observation

Habit	Botanical Name	Local Name	Pollen (P) /nectar (N)	Flowering Time	Source	Abund ance
Tree	*Accacia hecatophylla*	Qudo	P and N	Sept-Feb	Major	+
	Cordia africana	Wanza	P and N	Oct-March	Major	r
	Croton macrostachyus	Bekanisa	P and N	June-Sept	Major	+
	Ficus sycomorus	Shola	P and N	May-Sept	Major	r
	Lannea welweschi	Quwa	P and N	Sept-Nov	Major	r
	Pterocurpus lucens	Amiraro	P and N	Nov - Dec	Major	+
	Syzigium guineense	Dokma	N	March-May	Major	2a
	Terminalia laxiflora	Ashure	P and N	Dec-May	Major	2b
	Turraeanthus africanus	Yechaka	P and N	March-April	Major	r
	Acacia seyal	Kesh	P and N	Sept-Nov	Minor	2a
	Mangifera indica	Mango	P and N	Dec-April	Minor	2a
	Annona senegalensis	Adegela	P and N	March-June	Minor	1
	Boswellia papyrifera	Etan zaf	P and N	Sept-Dec	Minor	1
	Breonadia salicina	Debesa	P and N	August-Dec	Minor	2a
	Catha edulis	Chat	P and N	Throughout	Minor	1
	Citrus somensis	Burtukan	P and N	May-Sept	Minor	+
	Coffea arabica	Coffee	P and N	Feb- August	Minor	1
	Combretum molle	Ageraei	P and N	April-July	Minor	1
	Dalbergia boehmii	Tseba	P and N	Feb-May	Minor	r
	Erythrina abyssinica	Ambelsh	P and N	Oct-Jan	Minor	2a
	Erythrina brucei	Embelsh	P and N	Oct-Jan	Minor	2a
	Eucalyptus saligna	Bahrzaf	P and N	Sept- Dec	Minor	1
	Faurea speciosa	Atete	P and N	Nov-Feb	Minor	2a
	Ficus ingens	Bambegle	P and N	Feb-Sept	Minor	2a
	Ficus lutea	Warka	P and N	August-Oct	Minor	r

	Ficus sycomorus	Arbu	P and N	July-Oct	Minor	1
	Ficus vasta	Hodo	P and N	July-Oct	Minor	r
	Gardenia ternifolia	Ankeda	P and N	Sept-Nov	Minor	1
	Gardenia volkensi	Gambela	P and N	Sept-Jan	Minor	2a
	Grewia mollis	Aroresa	P and N	July-Sept	Minor	1
	Kotschya africana	Sseqe	P and N	March-June	Minor	r
	Loncocarpus laxiflorus	Afud	P and N	Dec-May	Minor	1
	Manilkara butuji	Butiji	P and N	Jan-April	Minor	2a
	Maytenus senegalensis	kombolch	P and N	Nov-April	Minor	2a
	Mytenus senegalensis	Agero	P and N	Nov-April	Minor	2a
	Persea americana	Avocado	P and N	Sept-Dec	Minor	r
	Phoenix reclinata	Zenbaba	P and N	June-Oct	Minor	r
	Pilostigma thunningii	Megel	P and N	May-Oct	Minor	2a
	Psidium guajava	Zeytuna	P and N	Oct-Nov	Minor	r
	Securidaca longepedanculata	Sheqet	P and N	March-June	Minor	r
	Strychnos innocua	Abunbuqo	P and N	April-July	Minor	1
	Vepris spp.	Zafi	P and N	Oct-Nov	Minor	2a
	Vitex doniana	kurkura	P and N	June-Oct	Minor	2a
	Ziziphus abyssinica	Qurqura	P and N	August-Nov	Minor	r
Shrubs	*Phoenix dactylifera*	Zenbaba	P and N	June-Sept	Minor	r
	Vernonia amygdolina	Grawa	P and N	Dec-Feb	Minor	2
	Ximenia americana	Bibi	P and N	August-Nov	Minor	2
Vines	*Cesalpinea* spp.	Ashi	P and N	Throughout	Minor	2
Climbers	*Cuccurbita pepo*	Duba	P and N	July-August	Minor	2
	Saba comorensis	Bishqore	P and N	August-Feb	Minor	2
Herbs	*Bidens pilosa*	Adeketsiya	P and N	Sept-Nov	Major	3
	Bidens prestinaria	Abumerery	P and N	Sept-Nov	Major	3
	Glycine spp.	Akuri	P and N	August-Oct	Major	1
	Guizotia abyssinica	Nug	P and N	Oct-Nov	Major	2b
	Guizotia scabra	Ada	P and N	Sept-Oct	Major	3
	Plantago larceolata	Arem	P	June-Oct	Major	3
	Solanum dasyphyllum	adro	P and N	June-Sept	Major	3
	Abelmoscus esculantus	Qeneqse	P and N	August-Oct	Minor	1
	Acanthus polystachius	Sokoru	P and N	Oct-Jan	Minor	1
	Amaranthus hybridus	Tsunda/Tika	P and N	June-Oct	Minor	r
	Capsicum minimum	Mitimita	P and N	May-July	Minor	r
	Vigna subterranea	Almdmese	P and N	August-Oct	Minor	r
Grasses	*Cyndon dectylon*	Serdo	P	May-Oct	Major	1
	Sorghum bicolar	Mashila	P	Oct-Dec	Major	2a
	Zea mays	Bekolo	P	July-Sept	Major	2b
	Andropogon schirensis	Abandu	P and N	May-Sept	Minor	1
	Cyndon nlemfuensis	Mergagogor	P and N	May-Oct	Minor	1
	Hyparrhenia diplandra	Cheto	P and N	Sept-Nov	Minor	1
	Hyperhina spp.	Muja	P and N	May-Sept	Minor	1
	Oxythenantra abyssinica	Bamboo	P and N	Sporadic	Minor	1
	Rhodus spp.	Yekoksar	P and N	July-Sept	Minor	+

Codes of cover-abundance: r= One or few individuals, += Occasional and less than 5%, 1= Abundant and with very low cover or less abundant but with higher cover; in any case less than 5% cover of total area, 2a= Very abundant and less than 5% cover, 2b= 5–12.5% cover, irrespective of number of individuals, 2c= 12.5–25% cover of total area, irrespective of number of individuals, 3= 25–50% cover of total area, irrespective of number of individuals, 4= 50–75% cover of total area, irrespective of number of individuals, 5= 75–100% cover of total area, irrespective of number of individuals

Season of flowering

In all three districts studied, there were two main flowering periods for honeybee plants, corresponding to two honey harvesting periods in the area. Seventy percent of the identified bee forage species flowered between September and November. The primary and most valuable bee forage plants during the first honey flow season included *Pterocarpus lucens, Bidens prestinaria, Glycine* species*, Guizotia abyssinica* (Fig 2)*, Guizotia scabra,* and other *Bidens* species.

Figur 2. Nug (*Guizotia abyssinica*)

In contrast, the second honey flow season, which was occurred from February to May, features woody plants such as *Cordia africana* (Fig 3)*, Syzygium guineense,* and *Terminalia laxiflora* as the main sources of pollen and nectar. The discussions and individual responses from beekeepers revealed that in the first season, flowered species yielded honey of varying quality, with more brood produced and poorer quality compared to the honey harvested in April of the second season.

Figur 3. Wanza (*Cordia africana*)

Species diversity, richness, and evenness of honeybee plant species

In the study area regarding the distribution of plants, the highest number of species has been collected from the highland area (Table 2). The results indicated that the abundance of tree bee forages was higher during the dry season which was vital for the second honey flow season. The value of the Shannon-Weaver diversity index indicated that in the highland area of the region, the honey bee flora species were more evenly distributed than the midland and lowland (Table 2). Moreover, the Shannon evenness value were ranged from 0.72-0.80 showing that the honeybee plant species counted in the study areas were evenly distributed in the sample plots and sites.

Table 2: Species diversity and species richness and evenness

Factors	Agro ecologies		
	Lowland	Midland	Highland
Species richness	63	55	71
Shannon species diversity	3.2	2.89	3.41
H’max (Ins) Shannon	4.14	4.00	4.26
Evenness	0.77	0.72	0.80

Bee pollen sources

The pollen samples were collected in different sites of the study area *Guizotia* species and *Terminalia laxiflora* were the major pollen-source honeybee plant species identified in the study areas (Table 3). On the other hand, *Plantago larceolata, Zea mays,* and *Bidenis* spp. were the secondary pollen sources of honey bee plant species, as the present findings indicated.

Table 3. Pollen sources for Bee Foraging in the study areas

N	Districts	Predominant pollen source	Secondary pollen source	Important minor pollen source	Minor pollen source
4	Bambasi	*Guizotia* spp.	*Plantago lanceolata*		
4	Bambasi	*Guizotia* spp.	*Plantago lanceolata*		
4	Bambasi	*Terminalia laxiflora*	*Zea mays, Bidenis* spp.	*Guizotia* spp.	
4	Homosha	*Terminalia laxiflora*	*Annona senegalensis*	*Syzigium guineense*	
4	Homosha	*Guizotia* spp.	Grass		
4	Homosha	*Guizotia*, spp.	*Turraeanthus africanus*	Grass species	
4	Mao komo	*Guizotia* spp.			
4	Mao komo	*Terminalia laxiflora*	*Plantago lanceolata*		
4	Mao komo	*Turraeanthus africanus*	*Plantago lanceolata*	*Guizotia* spp	

Botanical name of honey

The honey pollen analysis was revealed a diverse array of 21 plant species that serve as nectar sources for honey production. Among these, *Guizotia scabra* and *Guizotia abyssinica* were emerged as the most significant contributors to monofloral honey, boasting an impressive frequency percentage of 62.13%. This indicated their prevalence and importance in the region's honey production. Furthermore, the melissopalynological analysis of honey samples highlighted the dominant pollen types present, pinpointed *Syzygium guineense* and *Turraeanthus africanus* as the primary tree plant species involved in the formation of monofloral honey (48.23%) in the study area. Their abundance reflected not only their role as essential nectar sources but also their ecological relevance within the local environment.

Dearth period for honeybees

In Benishangul Gumuz, beekeepers have observed that the peak periods of food scarcity were occurred during the rainy season, from late July to August, and during the dry season, from December to January. During these times, there are limited flowering plants, which means fewer sources of pollen and nectar for the bees. To help support the bee colonies through these two challenging periods, it was crucial to provide them with supplemental food and water, as well as to conduct regular inspections of the colonies. The group discussions also revealed that smallholder farmers in the study areas were the primary users of pesticides, which negatively impacts both the honey bees and the plant species they rely on, leading to increased cases of honey bee colony absconding. Furthermore, the region has experienced a rapid biodiversity loss in bee forage due to deforestation and the expansion of cultivated land.

DISCUSSION

The findings from the study conducted in Benishangul Gumuz, western Ethiopia, reveal a robust ecological framework supporting honeybee foraging, characterized by a diverse array of flora. The identification of seventy-one plant species as forage sources for honeybees underscores the ecological richness of the region. This diversity is attributed to both naturally occurring flora and cultivated crops, including oilseeds, cereals, pulses, and horticultural varieties, which collectively enhance the beekeeping potential in the area. The results align with previous research by Addi and Bareke (2019), who documented seventy-four honeybee forage species in southwestern Ethiopia, indicating a regional consistency in floral diversity that supports apiculture. Such findings highlight the importance of maintaining ecological integrity in agricultural landscapes to sustain honeybee populations and, by extension, local biodiversity.

The value of the Shannon-Weaver diversity index in this study provides critical insights into the distribution patterns of honeybee forage species across different ecological zones. The higher evenness observed in the highland areas compared to midland and lowland regions suggests that the floral resources available to honeybees are more uniformly distributed, thereby potentially enhancing pollination efficiency and honey production. This observation corroborates the work of Wubie et al. (2014), who noted greater species diversity and richness in highland agro-ecological systems. While the evenness values ranging from 0.72 to 0.80 indicate a relatively balanced distribution of honeybee forage species, they are lower than those reported by Debissa and Amsalu (2006), which ranged from 0.79 to 0.89. This difference may reflect variations in sampling methods, ecological conditions, or the specificities of regional flora. However, the values are notably higher than those documented by Addi and Bareke (2019), underscoring the uniqueness of the Benishangul Gumuz ecosystem.

The present study's findings highlight the significant role of various herbaceous and woody plant species as forage resources for honeybees in the study area. Notably, *Bidens prestinaria*, *Guizotia abyssinica*, *Guizotia scabra*, *Sorghum bicolor*, and *Bidens pilosa* were identified as abundant species that contribute to the floral diversity essential for honey production. The presence of *Bidens spp*., *Guizotia scabra*, and *Plantago lanceolata* in both forested and cultivated landscapes underscores their ecological importance during the first honey flow season, corroborating the observations made by Degaga (2017) in the Jimma Zone, Southwest Ethiopia. During the second honey flow season in April, beekeepers indicated that *Syzygium guineense* and *Terminalia laxiflora* serve as critical forage sources due to their profusion of flowers, which provide vital nutritional resources for honeybees. This observation aligns with existing literature that recognizes the importance of these species in enhancing honey production, particularly during periods of resource scarcity. The increased abundance of tree bee forages during the dry season is particularly noteworthy, as it supports the notion that the availability of floral resources is closely tied to seasonal variations. This finding is consistent with Abebe et al. (2016), who documented that shrubs, crops, forbs, and certain woody plants constitute the primary bee forage from October to December, while the flowering of woody plants predominates as a source of pollen and nectar from February to May in the Assosa, Homosha, and Mao Komo districts of Benishangul Gumuz.

Furthermore, the belief among local beekeepers that the flowering period of *Syzygium guineense* serves as an indicator for honeybee colonies to prepare for honey production highlights the interconnectedness of ecological knowledge and beekeeping practices in the region. Research has established *Syzygium guineense* as a significant nectar source for *Apis mellifera*, thereby reinforcing its role in supporting honey production (Storrs 1995). Similar studies have also identified *Syzygium guineense* as a predominant nectariferous plant species in the Sudano-Guinean transition zone in Benin, emphasizing its importance in honey accumulation within hives (Yedomonhan 2009).

The primary flowering period for honey plants in Ethiopia, occurring from September to November and again from April to May, reflects the influence of the country's bimodal rainfall pattern (Teferi 2018). However, the unique climatic conditions of Benishangul Gumuz, characterized by a singular long rainy season lasting from May to November, necessitate a reevaluation of these patterns in the context of honey production. The findings of this study not only corroborate previous research but also emphasize the need for adaptive management strategies that consider the specific ecological and climatic characteristics of the region to optimize honey production.

The identification of 70% of the bee forage species flowering between September and November reinforces the significance of this time frame for beekeeping activities in the study area. This observation is consistent with Wubie et al. (2014), who reported a peak in flowering activity from August through October, particularly in August and September. The findings indicate that the first flowering season yields honey of varying qualities, with beekeepers noting that honey produced during this period tends to have more brood but lower quality than the honey harvested in April from woody plants. This suggests that floral resources' nutritional composition and availability during different seasons may significantly affect honey quality and overall beekeeping productivity.

While Wubie et al. (2014) documented a broader variety of pollen source plant species, our study highlights the importance of specific species such as *Guizotia* spp. and *Terminalia laxiflora* as primary pollen sources within the study area. This discrepancy may be attributed to differences in sampling methodologies or ecological variances between regions. The melissopalynological analysis conducted by Tulu et al. (2023) further supports this notion, revealing a predominance of multifloral honey samples with significant contributions from *Eucalyptus camaldulensis* and other lowland bee forages. The comparative analysis reveals that while certain species like *Terminalia* spp. and *Guizotia* spp. serve as critical pollen sources, their classification as secondary in other studies underscores the need for localized assessments to capture the dynamics of bee forage availability.

Moreover, the seasonal patterns observed from late July to August and during the dry season highlight the complexities of honeybee foraging behavior and the adaptability of beekeeping practices to local environmental conditions. The reliance on diverse pollen sources across different agroecological zones emphasizes the need for beekeepers to be aware of the specific flowering patterns and forage availability in their respective areas.

In discussing the findings of our research, it's clear that seasonal dynamics play a critical role in the health and stability of bee populations in the study area. The limited availability of flowering plants from late July to August and the dry season from December to January creates a challenging environment for bees. During these months, the lack of pollen and nectar sources significantly weakens bee colonies. This aligns with previous studies highlighting how resource scarcity directly impacts bee health and colony survival (Teklay 2011).

The situation gets even more complicated with the indigenous practice of burning forest areas from January to March. While this may serve certain agricultural or ecological purposes, it seems to push many bee colonies to abscond. It's interesting to note that this behavior is a survival strategy for bees when their habitat is compromised. Previous research has shown similar patterns, where habitat destruction leads to increased rates of colony abandonment (Belsky and Joshi 2019).

Moreover, the role of smallholder farmers using pesticides cannot be overlooked. Our discussions revealed that these farmers are major contributors to the pesticide problem in the region. The fact that many farmers apply pesticides multiple times during a growing season, as noted by Deressa and Alemu (2022), raises serious concerns. The negative impact of pesticides on both honey bees and the flowering plants they depend on is well-documented. It creates a vicious cycle: pesticides weaken bee colonies, which in turn affects pollination and the health of local flora, ultimately leading to fewer resources for the bees.

Conclusıon: In the Benishangul Gumuz regional state of Ethiopia, beekeeping plays a crucial role. It contributes significantly to household cash income, which is used for taxes, clothing, and school fees. The study identified 71 plant species that serve as forage sources for honeybees, with two main flowering periods corresponding to the honey harvesting seasons. In the region, the most abundant honeybee flora includes *Pterocarpus lucens, Bidens prestinaria, Guizotia species, Cordia africana, Syzygium guineense,* and *Terminalia laxiflora*. Approximately 70% of the bee forage species bloom from September to November, with key plants such as *Pterocarpus lucens, Bidens prestinaria, and Guizotia* species contributing significantly during the first honey flow season. In the second season, from February to May, woody plants like *Cordia Africana, Syzygium guineense,* and *Terminalia laxiflora* become the primary sources of pollen and nectar. *Guizotia scabra* and *Guizotia abyssinica* are significant for monofloral honey production, observed with a frequency of 62.13%. Research is needed to evaluate the nutritional value of the identified species of pollen and nectar sources. Promoting agroforestry systems that integrate bee-friendly plants within and around agricultural fields is also important. Furthermore, to support bee colonies during critical food shortages, we must provide supplemental food and water and conduct regular inspections. Finally, rapid biodiversity loss due to deforestation and the expansion of cultivated land poses a significant threat to the region's forage availability for bees.

Acknowledgment: The author expresses gratitude to the livestock researchers and field assistants at the Assosa Agricultural Research Center, as well as the Holleta Bee Research team. They would also like to extend their heartfelt thanks to the Ethiopian Biodiversity Institute Assosa Biodiversity Center for their support in identifying bee forage both in the field and the herbarium.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical statement: The ethical statement is not applicable to this study and does not involve any animals that would require approval from the ethics committee.

Funding: This project is funded by the Ethiopian Institute of Agriculture Research and the authors acknowledged the financial support.

Statements and Declarations: The author declares they have no competing interests or personal relationships that could influence this work.

REFERENCE

Abebe A, Tadesse Y, Equar Y, Faji M. and Alebachew H. Analysis of honey production systems in three agro-ecologies of Benishangul-Gumuz, Western Ethiopia. Journal of Agricultural Extension and Rural Development, 2016; 8(3): 29-38. DOI: https://doi.org/10.5897/jaerd2014.0705.

Addi A and Bareke T. Floral resources diversity and vegetation types important for honeybees in Ethiopia. Asian Journal of Forestry; 2019; 3(2). DOI:https://doi.org/10.13057/asianjfor/r030203.

Addi A, Wakjira K, Kelbessa E. and Bezabeh A. Honeybee forages of Ethiopia. Holeta Bee Research Center, Addis Ababa, Ethiopia, 2014.

Adgaba N. Atlas of pollen grains of major honeybee flora of Ethiopia. Holetta bee research centre, Holetta, Ethiopia, 2007.

Assosa Agricultural Research center (AsARC). Results of farming system survey in Benishangul Gumuz regional state. Ethiopian institute of agricultural research; Assosa Agricultural Research Center, Assosa, 2006. (Unpublished).

Begum HA, Iqbal J. and Aziz A. Characterization of pollen profile of *Apis mellifera* L. in arid region of Pakistan. Saudi journal of biological sciences, 2021; *28*(5): 2964-2974. https://doi.org/10.1016/j.sjbs.2021.02.035.

Belay A, Haki GD, Birringer M, Borck H, Lee YC, Cho CW, Kim KT, Bayissa B, Baye K. and Melaku S. Sugar profile and physicochemical properties of Ethiopian monofloral honey. International Journal of Food Properties, 2017; *20*(11): 2855-2866. https://doi.org/10.1080/10942912.2016.1255898.

Belsky J and Joshi NK. Impact of biotic and abiotic stressors on managed and feral bees. Insects, 2019; *10*(8): 233. https://doi.org/10.3390/insects10080233.

CSA. 2018. CSA (Central Statistical Authority). Agricultural Sample Survey: Report on Livestock, and Livestock Characteristics, II, CSA, Addis Ababa, Ethiopia (2018), 2017; 28-29, No 587.

Debissa L and Amsalu B. August. Botanical inventory and phenology of bee plants in rift valley regions of East Showa Zone. The Role of Agricultural Universities/Colleges in Transforming Animal Agriculture in Education. In Research and Development in Ethiopia: Challenges & Opportunities. Proceedings of the 13th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, 2006.

Degaga AH. Identification of honey source bee floras during major and minor honey harvesting seasons in Jimma Zone, Southwest Ethiopia. Journal of Environment and Earth Science, 2017; *7*(3): 25-32.

Deressa DA and Alemu K. Assessment of Pesticide Use by Farmers in Assosa District, Benishagul Gumuz National Regional State of Ethiopia. Journal of Health and Environmental Research, 2022; 7(1): 37-42. https://doi.org/10.11648/j.jher.20220801.16.

Haftom Gebremedhn HG, Zelealem Tesfay ZT, Girmay Murutse GM and Awet Estifanos AE. Seasonal honeybee forage availability, swarming, absconding and honey harvesting in Debrekidan and Begasheka watersheds of Tigray, Northern Ethiopia, 2013. http://www.lrrd.org/lrrd25/4/haft25061.htm.

Hedberg I. Flora of Ethiopia and Eritrea. In The Biodiversity of African Plants: Proceedings XIVth AETFAT Congress 22–27 August 1994, Wageningen, The Netherlands, 1996, :802-804. Springer Netherlands. https://doi.org/10.1007/978-94-009-0285-5_104.

Jacobs FJ, Simoens C, Graaf D and Deckers J. Scope for non-wood forest products income generation from rehabilitation areas: focus on beekeeping. Journal of the Drylands, 2006; 1(2): 171-185. http://hdl.handle.net/1854/LU-376496.

Louveaux J, Maurizio A and Vorwohl G. Methods of melissopalynology. Bee world, 1978; *59*(4): 139-157. https://doi.org/10.1080/0005772x.1978.11097714.

National Metrological Agency (NMA). Rainfall and Temperature historical data in Asosa area, Benishangul Gumuz Regional State, Ethiopia, 2017.Unpuplished.

Silici S and Gökceoglu M. Pollen analysis of honeys from Mediterranean region of Anatolia. Grana, 2007; 46(1): 57-64. https://doi.org/10.1080/00173130601138783.

Storrs AE. Know your trees. Some common trees found in Zambia. Zambia: Regional Soil Conservation Unit (RSCU), 1995. https://books.google.com.et/books?id=-24pPwAACAAJ.

Reinhard F and Admasu A. Honeybee flora of Ethiopia. DED-Weikersheim: Margraf, Germany, 1994. http://catalog.hathitrust.org/api/volumes/oclc/31749347.html.

Teferi K. Status of Beekeeping in Ethiopia-a review. Dairy and Vet Sci J, 2018; *8*(4): 555-743. https://doi.org/10.19080/jdvs.2018.08.555743.

Teklay A. Seasonal availability of common bee flora in relation to land use and colony performance in Gergera Watershed Atsbi Wemberta District, Eastern Zone of Tigray, Ethiopia (Doctoral dissertation, Hawassa University), 2011.

Tesfaye O, Mekonen E and Disa A. Botanical origin and physicochemical composition of *Apis mellifera* L. Honey from western Oromia, Ethiopia. Asian Journal of Bio Science, 2023; 16(1): 40-51. https://doi.org/10.3923/ajbs.2023.40.51.

Tulu D, Aleme M, Mengistu G, Bogale A, Bezabeh A and Mendesil E. Melissopalynological analysis and floral spectra of *Apis mellifera* scutellata Lepeletier bees in different agroecologies of southwest Ethiopia. Heliyon, 2023; 9(5). https://doi.org/10.1016/j.heliyon.2023.e16047.

Westhoff V, Van der Maarel E. The Braun-Blanquet approach. In Classification of Plant Communities: Whittaker, R.H., Ed: Springer: Hague, 617-726, Netherlands, 1973: https://doi.org/10.1007/978-94-010-2701-4_20.

Woody Biomass Inventory and Strategic Planning Project (WBISPP). Report on natural grazing lands and livestock feed resources, Benishangul Gumuz Regional State. 2003.

Wubie AJ, Bezabeh A and Kebede K. Floral phenology and pollen potential of honey bee plants in North-East dry land areas of Amhara region, Ethiopia. IOSR Journal of Agriculture and Veterinary Science, 2014; 7(5): 36-49. https://doi.org/10.9790/2380-07513649.

Yedomonhan H. Honey plants and potential for honey production in Guinean and Sudano-Guinean areas of Benin. Doctoral thesis from the University of Abomey-Calavi (Benin), FAST/UAC, 2009.