INNSPUB

Journal of Biodiversity and Environmental Sciences | JBES
ISSN: 2220-6663 (Print); 2222-3045 (Online)
Website: https://www.innspub.net
E-mail contact: info@innspub.net
Vol. 29, Issue: 2, p. 10-21, 2026

RESEARCH PAPER OPEN ACCESS

Diversity of wild and honey bees in relation with melliferous plants in northern Côte d'Ivoire, West Africa

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Key words: Conservation, Pollen, Nectar, Ecosystem service, Korhogo

Received: 18 July, 2026 **Accepted:** 28 July, 2026 **Published:** 04 August, 2026

DOI: https://dx.doi.org/10.12692/jbes/29.2.10-21

ABSTRACT

Melliferous plants are crucial for bee conservation since they constitute their main food resources. Unfortunately, knowledge on melliferous plants is poorly documented in the Sudanese savannas of West Africa, particularly in northern Côte d'Ivoire, where ecosystems and biodiversity are threatened by land use intensification and increasing degradation of natural habitats. This study for the first time focused on melliferous plants in northern Côte d'Ivoire. It aimed to know and conserve food resources of bees. Sampling was done in Loufa within the department of Korhogo. Bee visits were observed from plant inflorescences during different flowering periods. The names of plant species visited by bees and the collected nutrients were also recorded. A total of 59 melliferous plants belonging to 54 genera and 27 families were visited by bees for nectar or pollen. Combretaceae and Fabaceae were the most visited plant families. In addition, *Combretum collinum*, *Combretum molle*, *Annona senegalensis*, *Azadirachta indica*, *Cassia arereh*, *Diospyros mespiliformis* and *Anogeissus leiocarpa* were the most attractive plant species. Bee species were distributed depending on plant species and collected nutrients. Bee richness was highest with *Cassia arereh* and *Combretum collinum*. The honey bee was recorded on all melliferous plants except *Hyptis suaveolens*. More than half (55.93%) of melliferous plants were visited for both nectar and pollen. About 23.73% of plants were visited only for nectar and 20.34% only for pollen. The findings are very relevant because they contribute to monitoring bee communities and their ecosystem services in northern Côte d'Ivoire.

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INTRODUCTION

Wild and honey bees in West Africa play important role in plant pollination and ecosystem functioning. Many studies showed that they are the best pollinators of crops (Klein *et al.*, 2007; Michener, 2007). Indeed, pollination by bees is vital for crops and wild plants (Ollerton *et al.*, 2011). However, pollination is one of the most important mechanisms in the maintenance of biological diversity and, in general, of the life on earth. It also avoids inbreeding with its long-term consequences of loss of genetic variability. Thus, it contributes to the biodiversity preservation through the plant species regeneration and the maintenance of all living beings whose survival depends on it. A loss of pollinators would unbalance the ecosystems according to Potts (2011). In addition to the pollination, some bee species, such as honey bee, produce honey and other highly valued products such as propolis, beeswax and royal jelly (Biesmeijer, 2006).

These hive products have long contributed to improving the living conditions of local populations in our regions, by increasing their means of subsistence. Bees can also be considered as important indicators for ecosystems management and conservation thanks to their great ability to react to environmental alterations (Zayed *et al.*, 2004; Zayed and Packer, 2005). To feed and live, most of bees need to collect a large amount of nectar and pollen from flowers. These nutrients constitute their main food resources. The survival of bees therefore strongly depends on the availability of plant resources in their environment. Unfortunately, bee populations declined due to the intensive land use resulting in the natural habitat degradation (Ollerton *et al.*, 2014), and therefore a reduction of food resources provided by melliferous plants (Forrest *et al.*, 2015).

Intimate knowledge of bees in relationship with their habitats and food resources (melliferous plants) would be beneficial to maintain bee diversity and ensure the continued provision of their ecosystem services. However, very little work has been devoted to melliferous plants in Africa and the south of Sahara, where the economy is based on agriculture (Aizen and Harder, 2009). In addition, the rare studies carried out on bees have been devoted to the honey bee *Apis mellifera*. In Côte d'Ivoire, although some studies have been carried out in Yamoussoukro and Daloa, hardly anything is known about the melliferous plants in the northern region, especially those in the department of Korhogo. The present study for the first time, proposed to identify the melliferous plants of Loufa, a locality of the department of Korhogo. It aimed to deepen knowledge of melliferous plants in northern Côte d'Ivoire in order to contribute to the conservation of bee communities.

MATERIALS AND METHODS

Study areas and study sites

This study was carried out in northern Côte d'Ivoire particularly, in the department of Korhogo (9°25′0.00″N–5°37′0.001″W). The department covers an area of 12,500 km² with 11 Sub-Prefectures. The climate is characterised by two seasons, including a dry season from November to April, during which the harmattan blows, and a rainy season from May to October with maximum precipitation in August (Aiwa, 2015). According to the phytogeographical division of Cote d'Ivoire, the department of Korhogo belongs to the Sudano-Guinean sector. The vegetation consists of open forests, savanna formations, gallery forests and forest islands which serve as sacred groves near the villages. In most places where agriculture was possible, the original vegetation has been modified and replaced by mosaics of fields and fallows. The study site was chosen in Loufa, a locality of the department. The vegetation of this area is essentially a wasteland dominated by an abundance of floral species. The locality is divided by a stream which dries up during the dry season. Cotton and maize are the main crops to which must be added mango and cashew. This study site was chosen for its high floral diversity which allows it to be representative of the vegetation in the department.

Data collection and data analysis

Data were collected for a whole year from January 2022 to December 2022, covering the two seasons (dry season and rainy season) in the department of Korhogo.

Botanical survey

Before starting the study, a botanical inventory was carried out in order to establish the list of floral species in Loufa. The applied methodology was the same as that used by Guinko many years ago and modified by Coulibaly *et al.* (2020) to inventory melliferous plants in Burkina Faso. Indeed, this inventory focused mainly on woody plants but, the herbaceous species foraged by bees during the study period were particularly identified and added to the list of melliferous plants. The identifications were confirmed by a botanist from the Laboratory of Plant Biology and Ecology (LaBEV) of Joseph Ki-Zerbo University in Ouagadougou as part of a collaboration with this institution. They were carried out using a key of identification and the book of Arbonnier on the plants of Sudanian savannas of Africa.

Identification of melliferous plants

Melliferous plants were identified by observing the movements of bees on flowers. All plants visited by at least one bee, were automatically considered as melliferous plants (Stein *et al.*, 2021). Plant species did not flower at the same time of a year. For that, they were grouped according to the seasons (Coulibaly *et al.*, 2020). Flowering plant species were monitored from 6 a.m. to 6 p.m. for 15 min per time slot. The monitored plant species were divided into three groups: frequently visited plants ((> 25 visits by bees in total; intensity of foraging “IF” = +++), moderately visited plants (15 – 25 visits; IF = ++), and scarcely visited plants (< 15 visits; IF = +). The type of nutrients collected by each bee species allowed to distinguish nectariferous plants (i.e. plants that were only visited for their nectar) to the polliniferous plants (Coulibaly *et al.*, 2020). Bees solely foraging at the base of the corolla and not touching the pollen-bearing anthers were assumed to collect nectar, whereas bees leaving the flowers with pollen easily visible in the ”pollen baskets” on the hind legs were assumed to collect pollen.

Capture and identification of bees

Bees were captured on the flowers for one year using sweep nets. Each plant species was observed five times during its flowering period. Bees captured were keep in the flasks containing alcohol (70%). Each flask was labeled including the name of site, the code of plant and the date of capture. All samples were convoyed to the laboratory for identification. Bees were identified in the laboratory of "Pôle Scientifique et d'Innovation, Université Félix Houphouët-Boigny" in Côte d'Ivoire. In the laboratory, the collected insects were dried. Then, bees were sorted and separated from the other insects. The specimens of small sizes were pinned on glitter card stock while the large specimens were pinned directly from the thorax. All specimens of bees were identified with a binocular magnifying glass thanks to a reference collection of West African bees set up by Coulibaly since 2015, a key of identification (abc Taxa) and Atlas Hymenoptera.

Data analysis

These statistical analyses were performed using STATISTICA software version 7.1. To compare the mean abundance of bees on the melliferous plant species, we used the analysis of variance (ANOVA) and Duncan’s test at 5% level. Shannon, Pielou's species evenness and Jaccard similarity indices were calculated to measure the diversity of bee and plant species.

RESULTS

Diversity of bees

The melliferous plants were visited by 16 species of bees belonging to three families (Apidae, Megachilidae and Halictidae). The family Apidae (10 species) was the most diversified (H' = 2.32), followed by Halictidae (H' = 0.81). No diversity was observed in the family Megachilidae, which recorded a single species. The values of Pielou's species evenness were highest for the family Halictidae (E = 1). The analysis of variances showed a significant difference between the average abundance of the *Apis mellifera* and that of other bee species ($F = 22.49$; $p < 0.05$) (Table 1).

Diversity of melliferous plants

A total of 102 plant species belonging to 83 genera and 36 families were recorded during the study.

Fabaceae totaling 22 plant species was the most diversified family, followed by Rubiaceae (ten species), Combretaceae (six species) and Lamiaceae (six species). The analysis of variances showed a significant difference between the richness of Fabaceae and that of other plant families (F = 5.258; p = 0.041). Among them, only 59 melliferous plant species belonging to 54 genera and 27 families were identified. So, melliferous plant species accounted for 57.84% of all inventoried plant species. They were composed by trees, shrubs, herbaceous and lianas. Fabaceae (16 species) was also the most diversified melliferous plant family. The analysis of variances showed a significant difference between the richness of Fabaceae and that of other plant families (F = 4.133; p = 0.077) (Fig. 1).

Table 1. Mean abundances of bee species

Bee species	Mean abundance	
Apis mellifera	3.03 ± 0.042[a]	
Hypotrigona gribodoi	0.15 ± 0.070[b]	
Meliponula bocandei	0.08 ± 0.028[b]	
Amegilla sp.	0.03 ± 0.014[b]	
Xylocopa scioensis	0.03 ± 0.014[b]	
Amegilla acraensis	0.02 ± 0.014[b]	
Ceratina sp.	0.02 ± 0.014[b]	
Creightonella discolor	0.02 ± 0.014[b]	F = 22.49; p < 0.05
Crocisaspidia sp.	0.02 ± 0.014[b]	
Dactylurina staudingeri	0.02 ± 0.014[b]	
Pseudapis interstitinervis	0.02 ± 0.014[b]	
Pseudapis sp.	0.02 ± 0.014[b]	
Seladonia lucidipennis	0.02 ± 0.014[b]	
Thrinchostoma petersi	0.02 ± 0.014[b]	
Xylocopa inconstans	0.02 ± 0.014[b]	
Xylocopa olivacea	0.02 ± 0.014[b]	

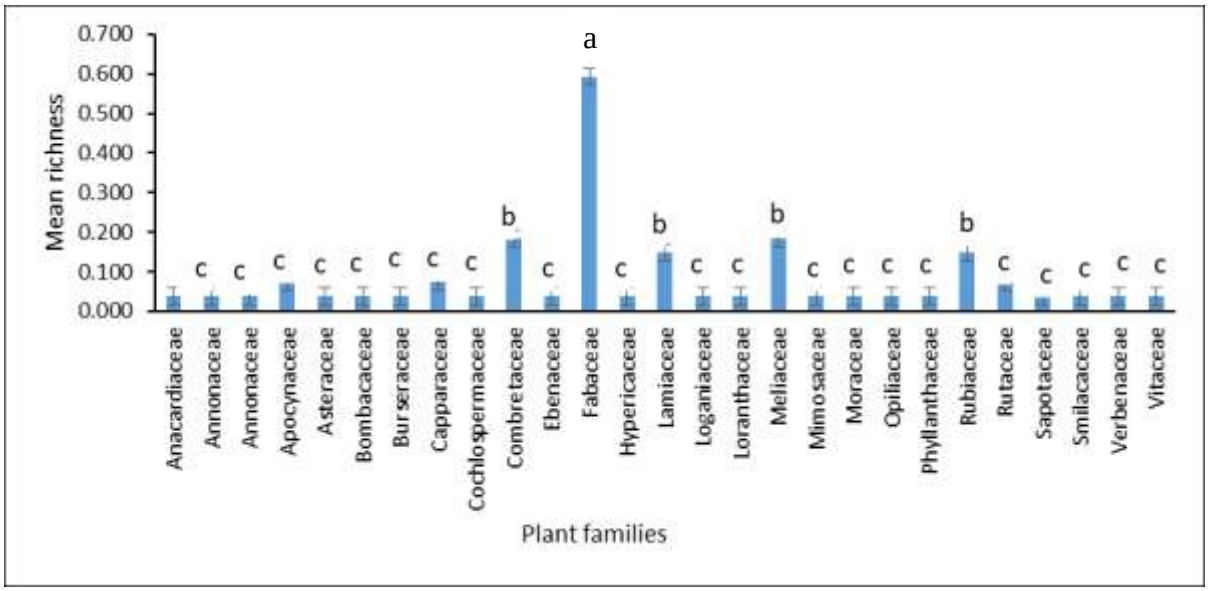

Fig. 1. Diagram indicating the average richness of melliferous plant families (Values with different letters on the same band are significantly different at p < 0.05 (Duncan's test)).

Values with different letters on the same column are significantly different at p < 0.05 (Duncan's test)

Morphological types of melliferous plants

A total of 696 bee visits were recorded on the flowers. Trees and shrubs were the most visited plants compared to herbaceous and lianas. Indeed, the visited plants were composed by 31 trees, 17 shrubs, seven herbaceous and four lianas (Table 2).

Table 2. Melliferous plant species recorded in the vegetation of Loufa

Plant species	Families	MT	FP	n	IF
Adansonia digitata L.	Bombacaceae	Tree	RS	15	++
Agelanthus dodoneifolius (DC.) Polhill & Wiens	Loranthaceae	Shrub	RS	8	+
Anacardium occidentale L. [cult.]	Anacardiaceae	Tree	EDS	15	++
Annona senegalensis Pers.	Annonaceae	Shrub	RS	27	+++
Anogeissus leiocarpa (DC.) Guill. & Perr.	Combretaceae	Tree	BRS	26	+++
Azadirachta indica L	Meliaceae	Tree	BRS	26	+++
Baissea multiflora A.DC.	Apocynaceae	Liana	BRS	8	+
Berlinia grandiflora (Vahl) Hutch. & Dalziel	Fabaceae	Tree	RS	8	+
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	Fabaceae	Tree	RS	8	+
Boscia angustifolia A.Rich.	Capparaceae	Shrub	BRS	8	+
Burkea africana Hook.	Fabaceae	Tree	RS	8	+
Cassia arereh Delile	Fabaceae	Tree	RS	26	+++
Cissus populnea Guill. & Perr.	Vitaceae	Liana	RS	15	++
Clausena anisata (Willd.) Hook.f. ex Benth.	Rutaceae	Shrub	DS	8	+
Cleome viscosa L.	Capparaceae	Herbaceous	RS	4	+
Cochlospermum planchonii Hook.f. ex Planch.	Cochlospermaceae	Shrub	RS	20	++
Cola cordifolia (Cav.) R.Br.	Malvaceae	Tree	RS	15	++
Combretum collinum Fresen.	Combretaceae	Shrub	BRS	29	+++
Combretum molle R.Br. ex G.Don	Combretaceae	Shrub	BRS	27	+++
Commiphora africana (A.Rich.) Engl.	Burseraceae	Shrub	DS	1	+
Crotalaria retusa L.	Fabaceae	Shrub	RS	8	+
Detarium microcarpum Guill. & Perr.	Fabaceae	Tree	RS	20	++
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	Tree	DS	20	++
Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	Tree	BRS	26	+++
Faidherbia albida (Delile) A. Chev.	Fabaceae	Tree	RS	15	++
Ficus sycomorus L.	Moraceae	Tree	RS	15	++
Gardenia erubescens Stapf & Hutch.	Rubiaceae	Shrub	DS	3	+
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	Shrub	DS	8	+
Guiera senegalensis J.F.Gmel.	Combretaceae	Shrub	BRS	15	++
Harungana madagascariensis Lam. ex Poir.	Hypericaceae	Tree	RS	20	++
Hexalobus monopetalus (A.Rich.) Engl. & Diels	Annonaceae	Tree	DS	8	+
Hoslundia opposita Vahl	Lamiaceae	Shrub	RS	1	+
Hyptis suaveolens (L.) Poit.	Lamiaceae	Shrub	RS	8	+
Isoberlinia doka Craib & Stapf	Fabaceae	Tree	DS	2	+
Khaya senegalensis (Desr.) A.Juss.	Meliaceae	Tree	DS	4	+
Leptadenia hastata (Pers.) Decne.	Apocynaceae	Herbaceous	RS	8	+
Mitracarpus hirtus (L.) DC.	Rubiaceae	Herbaceous	RS	8	+
Opilia amentacea Roxb.	Opiliaceae	Liana	RS	8	+
Parkia biglobosa (Jacq.) R.Br. ex G.Don	Mimosaceae	Tree	DS	20	++
Pericopsis laxiflora (Benth.) Meeuwen	Fabaceae	Tree	BRS	8	+
Phyllanthus muellerianus (Kuntze) Exell	Phyllanthaceae	Herbaceous	RS	4	+
Piliostigma reticulatum (DC.) Hochst.	Fabaceae	Shrub	RS	8	+
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabaceae	Tree	RS	8	+
Pseudoconyza viscosa (Mill.) D'Arcy	Asteraceae	Herbaceous	RS	15	++
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae	Shrub	DS	15	++
Senna occidentalis (L.) Link	Fabaceae	Shrub	RS	4	+
Senna siamea (Lam.) Irwin & Barneby	Fabaceae	Tree	DS	8	+
Senna tora (L.) Roxb.	Fabaceae	Tree	RS	4	+
Sida acuta Burm.f.	Malvaceae	Herbaceous	RS	8	+
Smilax anceps Willd.	Smilacaceae	Liana	RS	1	+
Sterculia setigera Delile	Malvaceae	Tree	DS	15	++
Strychnos spinosa L.	Loganiaceae	Tree	BRS	2	+
Tectona grandis L.f. [cult.]	Verbenaceae	Tree	DS	8	+
Terminalia macroptera Guill. & Perr.	Combretaceae	Tree	DS	15	++
Vachellia tortilis (Forssk.) Galasso & Banfi	Fabaceae	Tree	DS	8	+
Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	Tree	DS	15	++
Vitex madiensis Oliv.	Lamiaceae	Tree	DS	8	+
Waltheria indica L.	Lamiaceae	Herbaceous	RS	3	+
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	Rutaceae	Tree	DS	20	++

Given are further the plant family, the flowering period (DS = dry season; BRS = beginning of rainy season; RS = rainy season; EDS = end of dry season), the total number of bee visitors (n) and the intensity of foraging (IF). Plant species were assigned to frequently visited species (> 25 visits in total, IF +++, indicated in bold), moderately visited species (15 – 25 visits, IF ++), and scarcely visited species (< 15 visits, IF +). MT: Morphological type; FP: Flowering period.

Intensity of foraging

Fabaceae (163 visits) and Combretaceae (112 visits) were the most visited plant families (Table 2). Their visits by bees account for approximately 23.42% and 16.09%, respectively. The intensity of foraging was highest (IF = +++) on trees and shrubs compared to herbaceous and lianas (Table 2). Indeed, four plant species mainly trees (*Anogeissus leiocarpa*, *Azadirachta indica*, *Cassia arereh*, and *Diospyros mespiliformis*) and also three plant species mainly shrubs (*Annona senegalensis*, *Combretum collinum and Combretum molle*) were highly visited by bees compared to the all lianas and herbaceous species. In addition, *Combretum collinum* totaling 29 bee visits was the most visited plant species, followed by *Combretum molle*, *Annona senegalensis*, *Azadirachta indica*, *Cassia arereh*, *Diospyros mespiliformis* and *Anogeissus leiocarpa* which totaled between 26 and 27 bee visits (Table 2).

Periods of melliferous plants availability

The majority of melliferous plants were identified in the rainy season (30 plant species), followed by the dry season (18 plant species). However, in the transitional periods between the two seasons, some bee species were also recorded. Thus, in beginning of the rainy season, ten melliferous plant species were recorded against a single plant species at the end of dry season.

The plant species identified in the rainy season therefore represented 50.85% against 30.51% in the dry season, 16.95% in the beginning of rainy season and 1.69% in the end of dry season (Table 2).

Table 3. Plant species and types of food resources collected by bees (P: Pollen; N: Nectar)

Plant species	Bee species	Families	P	N
Adansonia digitata L.	*Apis mellifera*	Apidae	x	x
Agelanthus dodoneifolius (DC.) Polhill & Wiens	*Apis mellifera*	Apidae	x	
	Pseudapis sp.	Halictidae	x	
Anacardium occidentale L. [cult.]	*Apis mellifera*	Apidae	x	x
Annona senegalensis Pers.	*Apis mellifera*	Apidae	x	x
	Hypotrigona gribodoi	Apidae	x	
Anogeissus leiocarpa (DC.) Guill. & Perr.	*Apis mellifera*	Apidae	x	x
Azadirachta indica L.	*Apis mellifera*	Apidae	x	
Baissea multiflora A.DC.	*Apis mellifera*	Apidae		x
Berlinia grandiflora (Vahl) Hutch. & Dalziel	*Apis mellifera*	Apidae		x
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	*Apis mellifera*	Apidae		x
Boscia angustifolia A.Rich.	*Apis mellifera*	Apidae	x	x
Burkea africana Hook.	*Apis mellifera*	Apidae	x	
Cassia arereh Delile	*Apis mellifera*	Apidae		x
	Dactylurina staudingeri	Apidae	x	
	Hypotrigona gribodoi	Apidae	x	
	Xylocopa inconstans	Apidae		x
Cissus populnea Guill. & Perr.	*Apis mellifera*	Apidae	x	x
Clausena anisata (Willd.) Hook.f. ex Benth.	*Apis mellifera*	Apidae		x
Cleome viscosa L.	*Apis mellifera*	Apidae		x
Cochlospermum planchonii Hook.f. ex Planch.	*Apis mellifera*	Apidae	x	x
Cola cordifolia (Cav.) R.Br.	*Apis mellifera*	Apidae	x	x
Combretum collinum Fresen.	*Apis mellifera*	Apidae	x	x
	Hypotrigona gribodoi	Apidae	x	
	Creightonella discolor	Megachilidae		x
	Pseudapis interstitinervis	Halictidae	x	
Combretum molle R.Br. ex G.Don	*Apis mellifera*	Apidae	x	
	Hypotrigona gribodoi	Apidae	x	
	Amegilla acraensis	Apidae	x	
Commiphora africana (A.Rich.) Engl.	*Apis mellifera*	Apidae	x	x
Crotalaria retusa L.	*Apis mellifera*	Apidae		x
Detarium microcarpum Guill. & Perr.	*Apis mellifera*	Apidae	x	
	Crocisaspidia sp.	Halictidae	x	
Dichrostachys cinerea (L.) Wight & Arn.	*Apis mellifera*	Apidae	x	
Diospyros mespiliformis Hochst. ex A.DC.	*Apis mellifera*	Apidae		x
	Ceratina sp.	Apidae	x	
Faidherbia albida (Delile) A. Chev.	*Apis mellifera*	Apidae		x

Ficus sycomorus L.	*Apis mellifera*	Apidae	x	x
Gardenia erubescens Stapf & Hutch.	*Apis mellifera*	Apidae	x	x
Gardenia ternifolia Schumach. & Thonn.	*Apis mellifera*	Apidae		x
	Amegilla sp.	Apidae		x
Guiera senegalensis J.F.Gmel.	*Apis mellifera*	Apidae	x	
Harungana madagascariensis Lam. ex Poir.	*Apis mellifera*	Apidae	x	
	Meliponula bocandei	Apidae	x	
Hexalobus monopetalus (A.Rich.) Engl. & Diels	*Apis mellifera*	Apidae		x
Hoslundia opposita Vahl	*Apis mellifera*	Apidae		x
Hyptis suaveolens (L.) Poit.	*Xylocopa olivacea*	Apidae	x	x
	Amegilla sp.	Apidae	x	
	Xylocopa scioensis	Apidae		x
Isoberlinia doka Craib & Stapf	*Apis mellifera*	Apidae	x	x
Khaya senegalensis (Desr.) A.Juss.	*Apis mellifera*	Apidae	x	x
Leptadenia hastata (Pers.) Decne.	*Apis mellifera*	Apidae	x	x
Mitracarpus hirtus (L.) DC.	*Apis mellifera*	Apidae	x	x
Opilia amentacea Roxb.	*Apis mellifera*	Apidae	x	
Parkia biglobosa (Jacq.) R.Br. ex G.Don	*Apis mellifera*	Apidae	x	x
Pericopsis laxiflora (Benth.) Meeuwen	*Apis mellifera*	Apidae	x	x
Phyllanthus muellerianus (Kuntze) Exell	*Apis mellifera*	Apidae	x	
Piliostigma reticulatum (DC.) Hochst.	*Apis mellifera*	Apidae		x
Piliostigma thonningii (Schumach.) Milne-Redh.	*Apis mellifera*	Apidae	x	x
	Xylocopa scioensis	Apidae		x
	Meliponula bocandei	Apidae	x	
Pseudoconyza viscosa (Mill.) D'Arcy	*Apis mellifera*	Apidae	x	x
Sarcocephalus latifolius (Sm.) E.A.Bruce	*Apis mellifera*	Apidae	x	
	Meliponula bocandei	Apidae	x	
Senna occidentalis (L.) Link	*Apis mellifera*	Apidae	x	x
Senna siamea (Lam.) Irwin & Barneby	*Apis mellifera*	Apidae	x	x
Senna tora (L.) Roxb.	*Apis mellifera*	Apidae		x
Sida acuta Burm.f.	*Apis mellifera*	Apidae		x
Smilax anceps Willd.	*Apis mellifera*	Apidae	x	x
Sterculia setigera Delile	*Apis mellifera*	Apidae	x	x
Strychnos spinosa L.	*Apis mellifera*	Apidae		x
Tectona grandis L.f. [cult.]	*Apis mellifera*	Apidae	x	x
Terminalia macroptera Guill. & Perr.	*Apis mellifera*	Apidae	x	x
	Seladonia lucidipennis	Halictidae	x	
Vachellia tortilis (Forssk.) Galasso & Banfi	*Apis mellifera*	Apidae	x	x
Vitellaria paradoxa C.F.Gaertn.	*Apis mellifera*	Apidae	x	x
Vitex madiensis Oliv.	*Apis mellifera*	Apidae	x	x
Waltheria indica L.	*Apis mellifera*	Apidae	x	
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	*Apis mellifera*	Apidae	x	x
	Thrinchostoma petersi	Halictidae	x	x

Types of nutrients collected by bees

A total of 180 visits were carefully analyzed to determine the type of nutrients collected by each bee species. More than half (55.93%) of melliferous plants were visited by bees for pollen and nectar, against 23.73% for nectar and 20.34% for pollen (Table 3).

Preferences of nutrient type by each bee species

Nine bee species (*Amegilla acraensis*, *Ceratina* sp, *Crocisaspidia* sp., *Dactylurina staudingeri*, *Hypotrigona gribodoi*, *Meliponula bocandei*, *Pseudapis interstitinervis*, *Pseudapis* sp. and *Seladonia lucidipennis*) collected only the pollen and, three bee species (*Creightonella discolor*, *Xylocopa inconstans* and *Xylocopa scioensis*) collected only the nectar. In addition, two bee species (*Xylocopa olivacea* and *Thrinchostoma petersi*) collected both nectar and pollen grains on the same plant. In effect, *Xylocopa olivacea* and *Thrinchostoma petersi* collected both nectar and pollen grains on *Hyptis suaveolens* and *Zanthoxylum zanthoxyloides*. As for *Amegilla* sp., it did not take both nectar and pollen grains at the same time on the same plant. This bee species collected only pollen on *Hyptis suaveolens* and only nectar on *Gardenia ternifolia*. The honey bee *Apis mellifera* took either pollen, or nectar and sometimes both nectar and pollen grains at the same time on the same plant. However, in most cases, the honey bee collected both nectar and pollen grains on the same plant. In rare cases, it took only the nectar or only the pollen (Fig. 2).

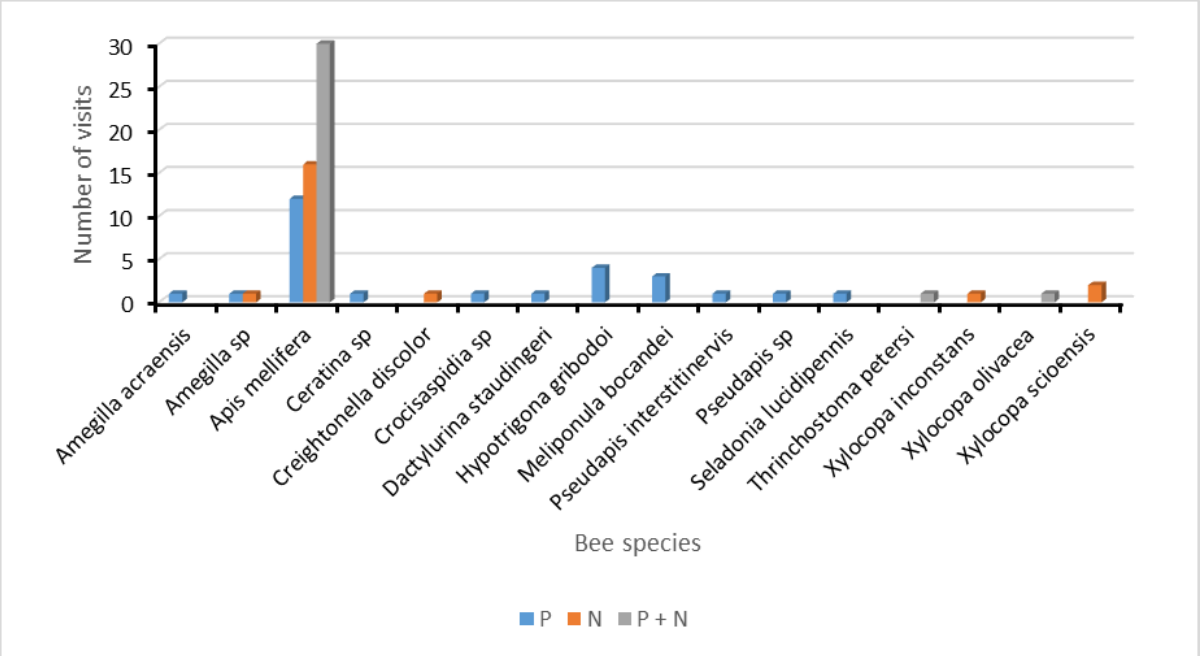

Fig. 2. Distribution of bee species according to the collected nutrients

Table 4. Distribution of bee species on each melliferous plant species

Plant species	Bee species
Combretum collinum Fresen.	*Apis mellifera* *Hypotrigona gribodoi* *Creightonella discolor* *Pseudapis interstitinervis*
Cassia arereh Delile	*Apis mellifera* *Dactylurina staudingeri* *Hypotrigona gribodoi* *Xylocopa inconstans*
Combretum molle R.Br. ex G.Don	*Apis mellifera* *Hypotrigona gribodoi* *Amegilla acraensis*
Hyptis suaveolens (L.) Poit.	*Xylocopa olivacea* *Amegilla* sp. *Xylocopa scioensis*
Piliostigma thonningii (Schumach.) Milne-Redh.	*Apis mellifera* *Xylocopa scioensis* *Meliponula bocandei*
Agelanthus dodoneifolius (DC.) Polhill & Wiens	*Apis mellifera* *Pseudapis* sp.
Annona senegalensis Pers.	*Apis mellifera* *Hypotrigona gribodoi*
Detarium microcarpum Guill. & Perr.	*Apis mellifera* *Crocisaspidia* sp.
Diospyros mespiliformis Hochst. ex A.DC.	*Apis mellifera* *Ceratina* sp.
Gardenia ternifolia Schumach. & Thonn.	*Apis mellifera* *Amegilla* sp.
Harungana madagascariensis Lam. ex Poir.	*Apis mellifera* *Meliponula bocandei*
Sarcocephalus latifolius (Sm.) E.A.Bruce	*Apis mellifera* *Meliponula bocandei*
Terminalia macroptera Guill. & Perr.	*Apis mellifera* *Seladonia lucidipennis*
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	*Apis mellifera* *Thrinchostoma petersi*
Adansonia digitata L. *Anacardium occidentale* L. [cult.]	

Anogeissus leiocarpa (DC.) Guill. & Perr.	
Azadirachta indica L.	
Baissea multiflora A.DC.	
Berlinia grandiflora (Vahl) Hutch. & Dalziel	
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	
Boscia angustifolia A.Rich.	
Burkea africana Hook.	
Cissus populnea Guill. & Perr.	
Clausena anisata (Willd.) Hook.f. ex Benth.	
Cleome viscosa L.	
Cochlospermum planchonii Hook.f. ex Planch.	
Cola cordifolia (Cav.) R.Br.	
Commiphora africana (A.Rich.) Engl.	
Crotalaria retusa L.	
Dichrostachys cinerea (L.) Wight & Arn.	
Faidherbia albida (Delile) A. Chev.	
Ficus sycomorus L.	
Gardenia erubescens Stapf & Hutch.	
Guiera senegalensis J.F.Gmel.	
Hexalobus monopetalus (A.Rich.) Engl. & Diels	
Hoslundia opposita Vahl	
Isoberlinia doka Craib & Stapf	*Apis mellifera*
Khaya senegalensis (Desr.) A.Juss.	
Leptadenia hastata (Pers.) Decne.	
Mitracarpus hirtus (L.) DC.	
Opilia amentacea Roxb.	
Parkia biglobosa (Jacq.) R.Br. ex G.Don	
Pericopsis laxiflora (Benth.) Meeuwen	
Phyllanthus muellerianus (Kuntze) Exell	
Piliostigma reticulatum (DC.) Hochst.	
Pseudoconyza viscosa (Mill.) D'Arcy	
Senna occidentalis (L.) Link	
Senna siamea (Lam.) Irwin & Barneby	
Senna tora (L.) Roxb.	
Sida acuta Burm.f.	
Smilax anceps Willd.	
Sterculia setigera Delile	
Strychnos spinosa L.	
Tectona grandis L.f. [cult.]	
Vachellia tortilis (Forssk.) Galasso & Banfi	
Vitellaria paradoxa C.F.Gaertn.	
Vitex madiensis Oliv.	
Waltheria indica L.	

The honey bee *Apis mellifera* was observed on all melliferous plants except *Hyptis suaveolens*. The other bee species were distributed differently on the melliferous plant species. The richness of bees was highest (four species) on *Cassia arereh* and *Combretum collinum*. These plant species were visited by two common bee species (*Apis mellifera* and *Hypotrigona gribodoi*) and four specific bee species (*Dactylurina staudingeri* and *Xylocopa inconstans* from *Cassia arereh*; *Creightonella discolor* and *Pseudapis interstitinervis* from *Combretum collinum*). *Combretum molle*, *Hyptis suaveolens*, *Piliostigma thonningii* were visited each by three bee species. *Agelanthus dodoneifolius*, *Annona senegalensis*, *Detarium microcarpum*, *Diospyros mespiliformis*, *Gardenia ternifolia*, *Harungana madagascariensis*, *Sarcocephalus latifolius*, *Terminalia macroptera* and *Zanthoxylum zanthoxyloides*, were visited each by two bee species. The other plant species were visited only by a single bee species '*Apis mellifera*' (Table 4).

DISCUSSION

Melliferous plant constitutes the main food resources for bees. For that, they are crucial for bee conservation and their ecosystem services such as pollination and honey production. Unfortunately, knowledge on melliferous plants is poorly documented in the Sudanese savannas of West Africa particularly in northern Côte d'Ivoire, where ecosystems and biodiversity are threatened by land use intensification and increasing degradation of

natural habitats (Coulibaly *et al.*, 2020). In Burkina Faso, only studies carried out by Guinko *et al.* (1992) and Nombré (2003) highlighted the melliferous plants. The first ones identified 159 melliferous plant species in Ouagadougou and its surroundings. The last ones identified 96 and 97 melliferous plant species respectively in Garango (province of Boulgou, Centre-East) and Nazinga (province of Nahouri, Centre-South). In Côte d'Ivoire, in the agroforestry area of the Higher Agronomic School of Yamoussoukro, Iritie *et al.* (2014) identified 160 melliferous plant species. In another study in Jean Lorougnon Guédé University of Daloa, Coulibaly *et al.* (2021) recorded 120 melliferous plant species. The current study is the first of kind to inventory melliferous plant in the department of Korhogo. The new findings will improve knowledge of melliferous plant species in Côte d'Ivoire. Combretaceae and Fabaceae were the most visited plant families by bees due to their abundance in the study area. Similar findings were reported in Burkina Faso by Coulibaly *et al.* (2020). Indeed, the diversity of Leguminosae, Rubiaceae, Combretaceae and Fabaceae is a main characteristic of natural formations in the Sudano-Guinean and Sudanian areas (Aloma, 2000; Nombré, 2003). The long flowering period of Combretaceae could justify the choice of bees for these plant species (Stein *et al.*, 2021). Combretaceae are, not only, one of plant families that dominate the vegetation of Sudanese savannas but, they can offer a more significant quantity of nectar and pollen to bees compared to other plant families. In this study, approximatively 57.84% of inventoried plant species were visited by bees. That confirms the fact that bees have a wide range in the choice of plants. This choice could be influenced by floral morphology, phenology and general floristic composition because various plant traits are known to influence visitors' attraction (Mitchell *et al.*, 2004; Brunet and Holmquist, 2009). Thus, the flowering periods should be considered in all study on melliferous plants. They provide information on the periods of nutrients availability for bees. In effect, the plant species do not flower at the same time in natural vegetation (Stein *et al.*, 2017). Flowering periods may vary according the time, the space and from one year to another, and also, depending on humidity conditions, individuals may flower in small quantities. Most melliferous plants were identified during the rainy season. In addition to woody plants, the present study took into account the herbaceous, which flower abundantly in the rainy season. However, some melliferous plant species were identified during the dry season. This period corresponds also to the flowering of several plant species in the Sudanese savannas of West Africa (Coulibaly *et al.*, 2020). This situation promotes nutrients availability throughout the year. Similar observations were made in the Sudano-Guinean area of central-western Benin in which we observed a variation of flowering periods (Yedomonhan *et al.*, 2009). Melliferous plant species are available all year round. That is an important asset because it allows continuous foraging activity in avoiding feeding bees as is done in Europe during winter (Iritie *et al.*, 2014). More than half of melliferous plant species were visited for both nectar and pollen, and the other plant species were visited either for nectar or for pollen.

The present findings contrast those of Dongock *et al.* (2004). In their study, the authors showed that 41% of plants were visited by bees for pollen and 23% for nectar in the Sudano-Guinean highlands of Western Cameroon. Nombré (2003) showed that some plant species considered as melliferous plant species in the Sudanian zone of Burkina Faso were not considered as melliferous in the Sudano-Guinean zone of central-western Benin. The aforementioned taxa were visited mostly for their nectar in the Sudanian area (Nombré, 2003), but the nectar production would depend on several parameters. Many studies showed that the quantity of produced nectar depends, among other things, on climate, soil and plant vigor (O'Toole and Raw, 2004). The most dominant families (Combretaceae and Fabaceae) in the present study area, can offer a greater quantity of nectar and pollen compared to the other plant families.

CONCLUSION

This study is the first of its kind to identify melliferous plant species in the department of Korhogo. Findings

showed that species from Fabaceae and Combretaceae families were the most attractive for bees. Regarding the plant species, *Combretum collinum*, *Combretum molle*, *Annona senegalensis*, *Azadirachta indica*, *Cassia arereh*, *Diospyros mespiliformis*, and *Anogeissus leiocarpa*, were the most attractive for bees. However, the greatest number of bee species were recorded on *Cassia arereh*, *Combretum collinum*, *Combretum molle*, *Hyptis suaveolens*, and *Piliostigma thonningii*. The melliferous plants flowered throughout the year in the study area. This is relevant for the development of beekeeping and for agriculture management. The knowledge of bee specificities with respect to melliferous plants could facilitate their sustainable management. Even if, the vegetation of Loufa is quite representative of Korhogo department, by its high diversity, a study that can cover the entire department is still appropriate.

ACKNOWLEDGMENTS

We would like to express sincere gratitude to DAAD for their support. We thank also the population of Loufa and all student assistants and many field assistants for pinning the bees and the fieldwork.

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