Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com/journal/sajb/home

OPEN ACCESS

Botany

Diversity of Honey Plants in Sub-Sudanese Savanna Area (Central-North of Côte d'Ivoire)

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| **Received:** 06.02.2019 | **Accepted:** 15.02.2019 | **Published:** 28.02.2019
DOI: 10.36347/sajb.2019.v07i02.004

Abstract | **Original Research Article**

Monitoring bees foraging activity in natural environment allows the identification of honey plants that provide them with the essential substances for honey production. In the Department of Katiola, located in the sub-Sudanese savannah area in Côte d'Ivoire, a floristic inventory and regular observations of the plants and bees were carried out for 12 consecutive months, within a radius of 1 km around an apiary of 16 colonized hives. A total of 126 honey species which was divided into 110 genera and 40 botanic families, have been identified. The Fabaceae family comprising of 23 species, was the richest in honey-yielding plants. Based on the nutrient collected by the bees, this flora is composed of 55 nectariferous species, 25 pollen species, 44 species both nectariferous and polliniferous, 1 resinous species and 1 species producing sweet juice of fruits. Microphanerophytes (47.62 %) are the predominant biological type. A total of 63 highly melliferous species have been identified. The effective use of these results could help improve beekeeping productivity.

Keywords: beekeeping, melliferous plant, inventory, Department of Katiola.

INTRODUCTION

Referring to them as the set of plant species from which bees collect substances (nectar, pollen, resin) to feed and to develop their various productions [1], honey plants are essential for beekeeping production in all parts of the world. Knowing them is of paramount importance for a sustainable beekeeping practice. As a matter of fact, [2] believes that any beekeeping practice must be preceded by several studies including the assessment of honey plant resources available in the environment chosen for this activity. In Côte d'Ivoire, although the practice of modern beekeeping has started since the 1970s [3], the fact remains that populations have been producing honey in traditional ways for many centuries. Nowadays, honey production is becoming more and more a source of substantial income for rural populations facing their ever-increasing needs. Despite this, there is a lack of information about honey plants in Côte d'Ivoire. Only a few researchers [4, 5] have examined this lack and tried to fix it to the best of their ability. But their work took place only in the Guinean forest and savanna transition zone in the center of the country. The northern part of Côte d'Ivoire is famous for its high production of honey; it is therefore rich in honey plants [4]. This study was initiated for a better knowledge of honey plant species, more specifically, those of the Department of Katiola where modern beekeeping started in Côte d'Ivoire [3].

General information on the study area

This study was carried out around an apiary located at 8°8'6.827 N latitude and 2°7'1.305 W longitude, near the village of Touro, in the southern part of the Department of Katiola (Fig 1), North-Central of Côte d'Ivoire. The population is dominated by indigenous Tagbanan and Mangôrô, to which are added several non-natives (Malian, Burkinabe, etc.) and non-indigenous groups (Baoulé, Senoufo, etc.). According to the 2014 General Census of Population and Housing (RGPH), it is estimated at 106,905 inhabitants. Agriculture is the main activity of the population. Food crops (maize, yams, rice, etc.) and cashew cultivation (cash crop) are widely practiced; as well as part time beekeeping. The climate of the Department is tropical and sub-humid [6]. Annual rainfall varies between 1,100 and 1,200 mm of rainfall, with an average temperature of around 27°C [7, 8]. The dry season, from November to February, is dominated by the harmattan, a dry, cool wind blowing from the Sahelian areas from north to south [6]. The vegetation consists of savannas and semi-deciduous forests [9]. The soils are

of ferralitic type with a predominantly sandy clay and gravelly texture [6].

MATERIALS AND METHODS

Data Collection

The nectar and pollen gathering area of the melliferous bee *Apis mellifera* is subjected to the structure of the vegetation. It varies from 0.5 to 3 km radius around the hive [10, 11], [12]. The work of [13] and [14] done in Benin, showed that almost all (98.6%) plants whose nectar and pollen are gathered by bees are within 1 km of the apiary. As a result, the nectar and pollen gathering radius considered for this study was 1 km around an apiary. The latter consisted of 16 hives colonized by *A. mellifera*.

On the foraging area, the adopted device for the inventory of honey plants is represented in Figure 2 and inspired by the work of [15] and [16]. It consists of 81 seed spots of 500 m² (20 m x 25 m) each, spaced from 200 meters. These seed spots were initially the subject of a comprehensive floristic surface inventory. Plant species have been identified based on the phylogenetic classification [17]. They were then visited regularly every two weeks, for 12 consecutive months, to make observations on the plants which were foraged by bees (honey plants) and to register them. The collected nutrient (nectar, pollen, sweet juice or resin) has been identified, to the naked eye or with a pair of binoculars as needed. Thus, nectariferous and/or polliniferous plants have been recognized based on the feeding behavior of nectar and pollen gathering-bees described by [15].

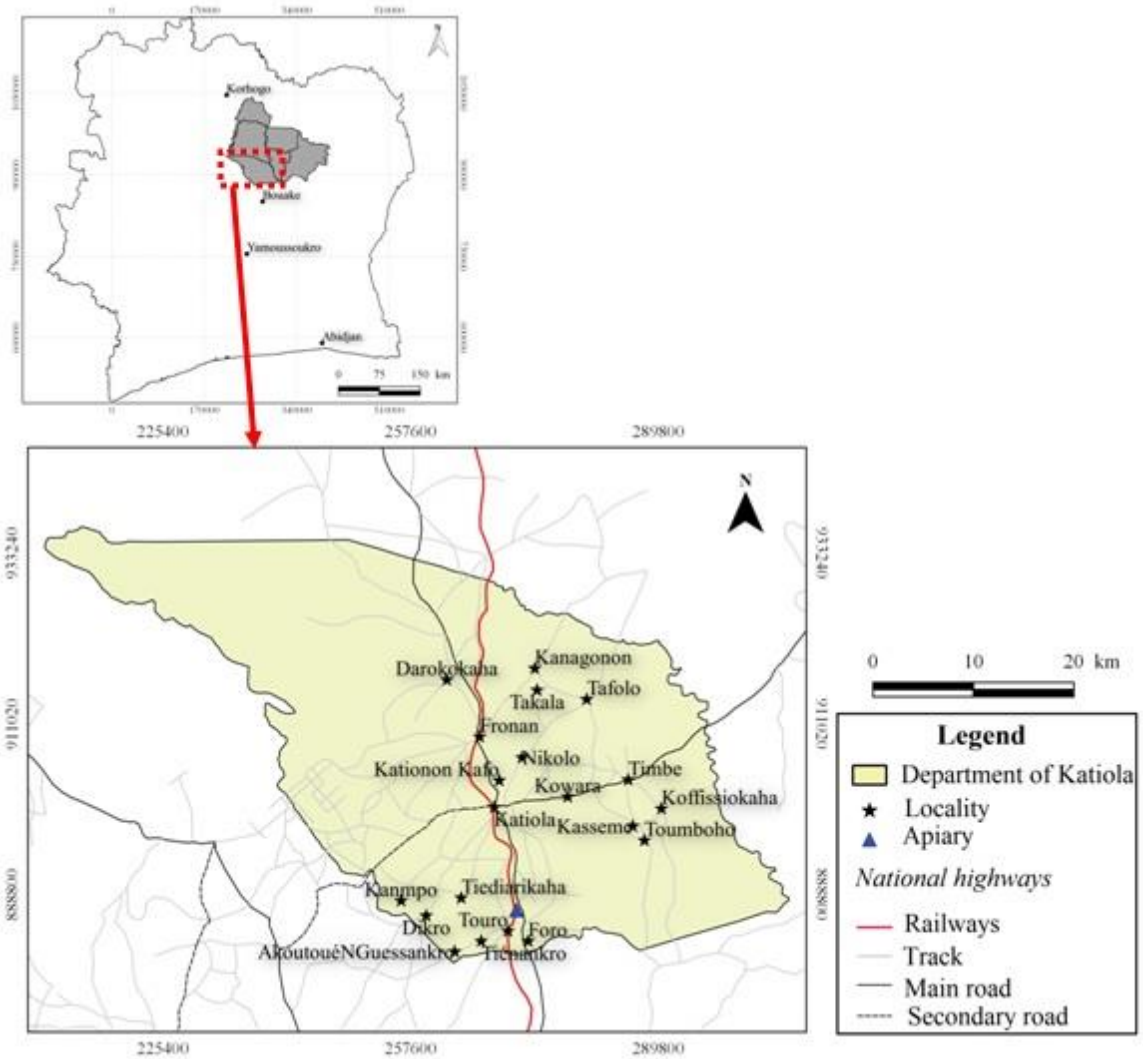

Fig-1: Map of the Department of Katiola located in the Central-North of Côte d'Ivoire

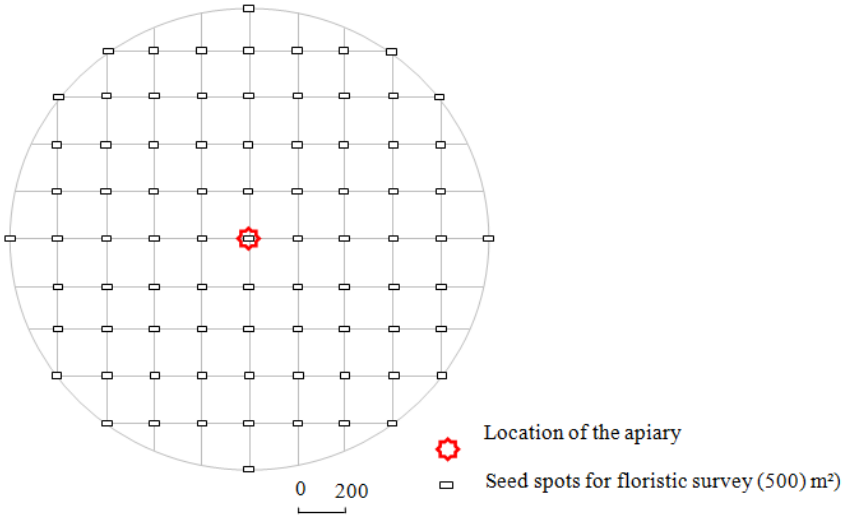

Fig-2: Distribution of floristic survey seed spots within the observation area

The nectar and pollen gathering rate was estimated as a percentage of flowers that bees visited in relation to all the plant flowers [4]. The flowering period and the color of the flowers (conferred by the corolla) were also recorded to better know the honey plants.

Data processing

The biological, morphological and phytogeographic distribution patterns of each identified honey plant species were derived from the work of [18] and [19]. The phenological profile was analyzed based on frequency and flowering duration [20]. Thus, two classes have been defined according to the frequency: on one side plants with a sub-annual cycle whose flowering progress is made in several cycles per year and on the other side plants with annual cycle (flowering process in a single cycle per year). Depending on the flowering duration, three classes were adopted: class I (one-month duration flowering), class II (two months duration flowering) and class III (three months duration flowering and more). In addition, three classes of nectar and pollen gathering intensity of the melliferous species were selected, based on the foraging (TB) whose maximum value is 30% [4, 15]:

- Class of low-foraged species (0 <TB <5%), referred to as +;
- Class of moderately foraged species (5 ≤ TB <10%), referred to as ++;
- Class of intensely foraged species (10 ≤ TB ≤ 30%), referred to as +++.

High melliferous value species are those whose nutrients (nectar and/or pollen) are available and intensely foraged by bees for a month and a half at least [21]. The XLStat 2014 software was used for Pearson correlation tests between the evolution of the monthly species richness of flowering plants and that of honey plants.

RESULTS

Composition of the honey flora around the apiary

A total of 126 melliferous species in 110 genera and 40 botanic families have been identified (Table 1). This represents 32.81% of the flora of the habitat and 35.49% of the species having flowered. The richest families of honey plants are Fabaceae (18%), Malvaceae (7%), Lamiaceae (5%), Asteraceae (5%), Rubiaceae (5%) and Sapindaceae (4%).

Among the melliferous species, 90% are dicotyledonous and 10% are monocotyledonous. Shrubs are the most represented morphological type with 35% (Figure 3). Regarding the biological type, microphanerophytes are the most predominant with 47.62%, i.e. 60 species. They are followed by nanophanerophytes (18.25%), mesophanerophytes (12.7%) and therophytes (11.9%). Each of the other biological types contains less than 3% of the honey plants.

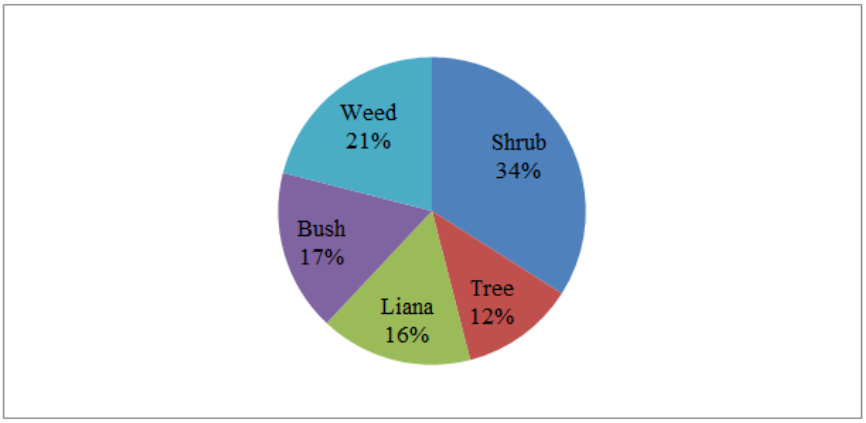

Fig-3: Distribution of honey plants as per morphological types

Regarding chorology, taxa in the Guinean and Congolese regions as well as in Sudan and-Zambezi are the most dominant (54.84%). They are followed by those from the Guinean and Congolese regions (17.74%), Sudanese and Zambezi (17.74%), of introduced taxa (8.87%) and endemic taxa from the block to the west of Togo (0.81%).

Temporal honey resources around the apiary

The nutrients collected by bees on honey plants are varied. In fact, 55 melliferous species are exclusively nectariferous (43.65%), 44 are both nectariferous and polliniferous (34.92%), 25 are solely polliniferous (19.84%) and 2 species provide other nutrients such as resin (0.79%) and sweet juice (0.79%).

Different flowering patterns were noted in identified honey plants. In fact, 94 species (or 74.6%) have an annual flowering cycle, lasting from 1 to 10 months, and 32 species (25.5%) have a sub-annual flowering cycle. Their flowering is sequentially spread over time. Thus, 92 honey species (73.01%) have a flowering duration of three months or more (class III). Those flowering for two months (class II) are 33 (26.19%). A single species (0.80%) flowered for one month (class I).

In terms foraging intensity, highly foraged plants dominate with 64 species (50.79%). Among them, both nectariferous and polliniferous species are the most predominant at 24.6% (Table 2). In addition, 33 species are moderately foraged, or 26.19% of which 11.12% are both nectariferous and polliniferous. Finally, 29 species are slightly foraged, or 23.02%.

According to the double criterion of flowering duration and foraging intensity, 63 high-value melliferous species were detected, i.e. 50% of the identified honey plants. 48 of these species flower for at least three months (class III) and 15 for two months (class II). This flora of interest includes 28 species, both nectariferous and polliniferous, 24 exclusively nectariferous, 10 solely polliniferous and 1 resinous species. Thus, a total of 52 highly melliferous species (41.27%) offer nectar to bees. Highly melliferous species include *Croton hirtus* L'Hérit. (Figure 4), *Adenia cissampeloides* (Planch ex Hook.) Harms (Figure 5), *Antigonon leptopus* Hook. & Arn, *Vitex doniana* Sweet and *Jacquemontia tamnifolia* (L.) Griseb (Table 1).

In addition, the white flowers are the most predominant with 35% of the honey flora (Figure 6). They are followed by yellow flowers, with 28% and multicolored flowers (13%). Those of orange color are the least represented, with 1%. Among the 63 species with high melliferous value, the predominant are the white and yellow flowers with 73.15%.

Table-1: List of honey plants identified around the apiary

Species	Tb	TC	TM	Class	Flowering Month												IB	Nut	CF
					J	F	Mh	Ap	Ma	Je	Jy	At	S	O	Nv	Dc			
Amaranthaceae																			
Alternanthera repens (L.) Link	Ch	GC-SZ	Weed	D									*	*	*	*	+	N	White
Celosia trigyna L.[#]	Th	GC	Weed	D					*	*	*	*	*	*	*		+++	N	White
Anacardiaceae																			
Anacardium occidentalis Linn.	mp	i	Shrub	D	*	*	*	*	*						*	*	+	N-Js	White and red
Lannea microcarpa Engl. & K.	mp	SZ	Shrub	D	*	*										*	++	N-P	Yellow and green
Mangifera indica L.	mP	i	Tree	D	*	*	*						*	*		*	+	N-Js	Yellow and red
Spondias mombin L.	mp	GC-SZ	Shrub	D			*	*									++	N	Yellow
Apocynaceae																			
Leptadenia hastata	mp	SZ	Liana	D				*	*								++	N	Green
Mondia whitei (Hook. F.) Skeels[#]	mp	GC-SZ	Liana	D							*	*	*				+++	N	Green and yellow
Parquetina nigrescens (Afzel.) Bullock[#]	mp	GC	Liana	D							*	*	*	*			+++	N-P	Violet
Araliaceae																			
Cussonia barteri Seemann Schefflera J.R. & G. Forst.[#]	mp	SZ	Shrub	D				*	*	*	*						+++	N-P	Green
Arecaceae																			
Borassus aethiopum Mart.[#]	MP	GC-SZ	Tree	M	*	*				*	*	*				*	+++	N-P	Yellow
Elaeis guineensis Jacq.[#]	mP	GC	Tree	M										*	*	*	+++	P	Yellow
Phoenix reclinata Jacq.	mp	GC-SZ	Shrub	M									*	*			++	P	Yellow
Asclepiadaceae																			
Exolobus patens (Decne.) Fourn.[#]	mp	GC	Liana	D	*								*	*	*	*	+++	N-P	White
Secamone afzelii (Schultes) K. Schum.[#]	mp	GC	Liana	D								*	*	*			+++	N	Yellow
Asteraceae																			
Aspilia africana (Pers.) Adams var. africana	np	GC	Bush	D	*							*	*	*	*	*	+	N-P	Yellow
Aspilia rudis Oliv. & Hiern[#]	np	SZ	Bush	D				*	*					*	*		+++	N-P	Violet
Bidens pilosa L.	Th	GC-SZ	Weed	D							*	*	*				+	N-P	Yellow
Eclipta prostrata L.[#]	Th	GC-SZ	Weed	D								*	*	*	*	*	+++	N-P	Yellow
Sonchus oleraceus L.	Th	SZ	Weed	D	*						*	*	*	*	*	*	++	N-P	Yellow
Tridax procombens L.[#]	Ch	GC-SZ	Weed	D				*	*	*	*	*	*	*	*		+++	P	Yellow
Cannabaceae																			

Trema orientalis auct., non (L) Blume	mp	GC-SZ	Shrub	D					*	*							+	N	Yellow and green
Chrysobalanaceae																			
Parinari curatellifolia Planch. ex Benth.[#]	mp	SZ	Shrub	D	*	*	*	*									+++	N	White and pink
Cleomaceae																			
Cleome gynandra L.	Th	GC-SZ	Weed	D							*	*	*	*			+	N	White
Cleome viscosa L.[#]	Th	GC-SZ	Weed	D					*	*					*	*	+++	N-P	Yellow
Combretaceae																			
Anogeissus leiocarpus (DC.) Guill. & Perr.	mp	SZ	Shrub	D								*	*	*			++	N-P	Green
Combretum paniculatum Vent.	mp	GC-SZ	Liana	D	*											*	+	N	Red
Combretum racemosum P. Beauv.	mP	GC	Liana	D	*	*							*	*		*	++	N	White
Terminalia laxiflora EngI.[#]	mp	SZ	Shrub	D				*	*	*							+++	N-P	White
Commelinaceae																			
Commelina diffusa Burm.f. subsp. diffusa	np	GC-SZ	Bush	M				*	*	*	*				*	*	+	N	Violet
Convolvulaceae																			
Ipomoea cairica (L.) Sweet[#]	mp	GC-SZ	Liana	D	*	*					*				*	*	+++	N-P	White
Ipomoea triloba L.	Th	GC	Herbe	D					*	*	*	*	*	*	*		+	N	Violet
Jacquemontia tamnifolia (L.) Griseb[#]	Th	GC-SZ	Weed	D										*	*		+++	N	Violet
Cyperus cyperoides (L.) Kuntze	Th	GC-SZ	Weed	M			*	*	*	*	*	*	*	*	*		+	P	Green
Cyperaceae																			
Cyperus rotondus L.[#]	Gr	GC-SZ	Weed	M							*	*	*				+++	P	Red
Kyllinga erecta Schumach.	Gr	GC-SZ	Weed	M						*	*	*	*				+	P	Green
Mariscus cylindristachyus Steud.	H	GC-SZ	Weed	M			*	*	*	*	*	*	*	*	*	*	+	P	Green
Euphorbiaceae																			
Croton hirtus L'Hérit.[#]	np	GC	Bush	D				*	*	*	*	*	*	*			+++	P	White
Croton macrostachyus Hochst. Ex Delile	mp	GC-SZ	Shrub	D			*	*	*								++	N-P	Yellow
Euphorbia heterophylla Linn.	Th	GC	Weed	D				*	*	*		*	*	*			++	N-P	Yellow
Mallotus oppositifolius (Geiseler) Müll. Arg.[#]	mp	GC-SZ	Shrub	D		*	*			*	*		*	*			+++	P	Yellow
Fabaceae																			
Acacia polycantha Willd.[#]	mp	SZ	Shrub	D			*	*	*	*							+++	N-P	Yellow

Acacia sieberiana var. villosa A. Chev.[#]	mp	SZ	Shrub	D			*	*									+++	N-P	White
Aeschynomene americana L.[#]	np		Bush	D	*									*	*	*	+++	N-P	Yellow and brown
Afrormosia laxiflora (Benth. ex Bak.) Harms[#]	mp	GC-SZ	Shrub	D				*	*								+++	N-P	White
Albizia ferruginea (Guill. & Perr.) Benth.	mP	GC-SZ	Tree	D			*	*	*								+	N-P	White
Albizia zygia (DC.) J.F. Macbr.[#]	mP	GC-SZ	Tree	D			*	*									+++	N-P	White and red
Calopogonium mucunoides Desv.[#]	mp	GC	Liana	D									*	*	*	*	+++	N	Violet
Cassia kirkii Oliv.[#]	np	GC	Bush	D								*	*				+++	N-P	Yellow
Daniellia olivera Hutch. & Dalz.[#]	mP	SZ	Tree	D	*	*										*	+++	N	White
Delonix regia (Hook.) Raf.	mp	GC-SZ	Shrub	D			*	*	*								++	N-P	Red
Detarium senegalense J.F. Gmel.[#]	mP	GC-SZ	Tree	D										*	*	*	+++	N	White
Dialium guineense Willd.	mP	GC	Tree	D										*	*	*	++	N	White
Dichrostachys cinerea (Linn.) Wight & Arn. subsp. Cinerea	mp	GC-SZ	Shrub	D		*	*	*	*			*	*				++	N-P	White and yellow; White and pink
Eriosema molle Hutch. ex Mi Ine-Redhead	np	GCW	Bush	D									*	*			+	N	Yellow
Erythrophleum suaveolens (Guill. & Perr.) Brenan	mP	GC-SZ	Tree	D		*	*	*									++	N	Yellow
Indigofera congesta Welw. Ex Baker[#]	np		Bush	D										*	*	*	+++	N	Orange
Leucaena glauca (Linn.) Benth.	mp	i	Shrub	D				*	*			*	*				+	N-P	White
Lonchocarpus cyanescens (Schummach & Thonn.) Benth.[#]	mP	GC-SZ	Liana	D						*	*	*	*				+++	N	Violet
Lonchocarpus sericeus (Poir.) Khunt.	mp	GC-SZ	Shrub	D				*			*	*	*				++	N	Violet
Mimosa invisa Mart. ex Colla	np	i	Liana	D	*								*	*	*	*	+	P	Pink
Parkia biglobosa (Jacq.) Benth.[#]	mp	SZ	Shrub	D	*	*	*									*	+++	N-P	Red
Piliostigma thonningii (Schum.) Millne-Redhead	mp	GC-SZ	Shrub	D					*	*	*	*	*				+	N	White
Pterocarpus erinaceus Poilr.[#]	mp	SZ	Shrub	D									*	*	*	*	+++	N-P	Yellow
Lamiaceae																			

Gmelina arborea Roxb.	mp	i	Shrub	D	*	*	*	*	*	*				*	*	*	++	N	Yellow
Hoslundia opposita Vahl[#]	np	GC-SZ	Bush	D				*	*			*	*	*	*		+++	N	White
Hyptis suaveolens Poit.[#]	np	GC-SZ	Bush	D			*	*	*			*	*	*	*		+++	N	Violet
Ocimum basilicum L.	np	GC-SZ	Bush	D											*	*	++	N	White
Ocimum canum Sims	np	GC-SZ	Bush	D							*	*	*				+	N	White
Tectona grandis Linn.f.	mP	i	Tree	D				*	*	*	*	*					++	N-P	White
Vitex doniana Sweet[#]	mp	GC-SZ	Shrub	D		*	*				*						+++	N	White and pink
Loganiaceae																			
Spigelia anthelmia L.	Th	GC	Weed	D				*	*	*		*	*	*			+	N	Violet
Malvaceae																			
Adansonia digitata L.[#]	mP	SZ	Tree	D					*	*	*	*	*				+++	N-P	White
Ceiba pentandra (Linn.) Gaerth.	MP	GC-SZ	Tree	D	*										*	*	++	N-P	White
Grewia carpinifolia Juss.	mp	GC	Liana	D				*	*	*	*	*					++	P	Yellow
Sida acuta Burm.f.[#]	np	GC	Bush	D				*	*			*	*	*	*	*	+++	N-P	Orange yellow
Sida rhombifolia L.[#]	np	GC-SZ	Bush	D							*	*	*				+++	N-P	Yellow
Sterculia tragacantha Lindl.	mP	GC-SZ	Tree	D		*	*										++	N	Yellow
Triumfetta rhomboidea Jacq.	np	GC-SZ	Bush	D									*	*	*	*	++	P	Yellow
Urena lobata L.[#]	np	GC-SZ	Bush	D								*	*	*	*		+++	N	Violet
Waltheria indica L.[#]	np	GC-SZ	Bush	D				*	*				*	*	*	*	+++	N-P	Yellow
Meliaceae																			
Azadirachta indica A. Juss.	mp	i	Shrub	D	*	*	*	*	*	*	*					*	+	N	White
Khaya senegalensis (Desv.) A. Juss.	mP	SZ	Shrub	D			*	*									++	N	Yellow
Pseudocedrela kotschyi (Schweinf.) Harms	mp	SZ	Shrub	D			*	*									+	N	Yellow
Trichilia emetica Vahl subsp. suberosa J.J.[#]	mp	SZ	Shrub	D		*	*				*	*					+++	N	Yellow
Moraceae																			
Ficus exasperata Vahl[#]	mp	GC-SZ	Shrub	D			*	*	*						*	*	+++	R	-
Ficus sur Forsk.	mp	GC-SZ	Shrub	D				*	*					*	*	*	++	Mt	-
Myrtaceae																			
Psidium guajava L.	mp	i	Shrub	D				*	*	*		*					++	N-P	White
Syzygium guineense var. macrocarpum EngI.[#]	mp	SZ	Shrub	D	*	*					*	*	*			*	+++	N-P	White
Nyctaginaceae																			
Boerhavia diffusa L.[#]	Ch	GC-SZ	Weed	D				*	*	*			*				+++	P	White
Nymphaea lotus L.[#]	Hyd	GC-SZ	Weed	D							*	*	*	*	*		+++	N-P	White
Olacaceae																			

Olax subscorpioidea Oliv.	mp	GC-SZ	Shrub	D	*										*	*	++	N	Yellow
Onagraceae																			
Ludwigia stolonifera (Guill. & Perr.)	Hyd	GC-SZ	Weed	D							*	*	*	*	*	*	++	N-P	Yellow
Passifloraceae																			
Adenia cissampeloides (Planch. ex Hook.) Harms[#]	mp	GC	Liana	D			*	*	*	*	*	*					+++	N-P	Green
Passiflora foetida L.	mp	GC	Liana	D					*	*		*	*				++	N	White
Phyllanthaceae																			
Antidesma venosum Tul.[#]	mp	SZ	Shrub	D				*	*	*	*						+++	N	Olive green
Bridelia ferruginea Benth.	mp	GC-SZ	Shrub	D				*	*								++	N-P	Orange yellow
Hymenocardia acida Tul.[#]	mp	GC-SZ	Shrub	D		*	*										+++	N-P	Red
Securinega virosa (Roxb. ex Willd.) Baill.[#]	np	GC-SZ	Bush	D			*	*	*	*	*	*	*	*			+++	N-P	Yellow
Poaceae																			
Andropogon gayanus Kunth var. gayanus	H	GC-SZ	Weed	M										*	*	*	+	P	Green
Andropogon tectorum Schum. & Thonn.	H	GC-SZ	Weed	M										*	*	*	+	P	Green
Oryza sativa L.	Th	GC-SZ	Weed	M										*	*		++	P	White
Zea mays[#]	Th	GC-SZ	Weed	M						*	*	*	*	*			+++	P	Green and violet
Polygalaceae																			
Securidaca longepedunculata Fresen.	mp	SZ	Shrub	D			*	*							*	*	+	N	Violet
Antigonon leptopus Hook. & Arn.[#]	mp	i	Liana	D			*	*	*	*	*	*	*	*	*	*	+++	N-P	Pink
Rubiaceae																			
Crossopteryx febrifuga (G. Don) Benth.	mp	GC-SZ	Shrub	D				*	*	*							++	N-P	White
Keetia venosa (Oliv.) Bridson	mp	GC-SZ	Liana	D							*	*					++	P	White
Nauclea latifolia Sm.[#]	mp	GC-SZ	Liana	D				*	*								+++	N	White
Spermacoce octodon (Hepper) J.-P. Lebrun & Stork[#]	np	GC-SZ	Bush	D								*	*	*			+++	N	White
Spermacoce stachydea DC.[#]	Th	GC-SZ	Weed	D								*	*	*			+++	N-P	White
Spermacoce verticillata L.[#]	np	GC-SZ	Bush	D								*	*	*	*	*	+++	N	White
Rutaceae																			
Citrus limon Burn. f.[#]	mp	i	Shrub	D				*	*	*	*						+++	N-P	White
Citrus sinensis (L.) Osbeck[#]	mp	i	Shrub	D			*	*									+++	N-P	White

Harrisonia abyssinica Oliv.	mp	GC-SZ	Shrub	D			*	*									+	N-P	White
Zanthoxylum Zanthoxyloides (Lam.) Zepern. & Timler[#]	mp	GC-SZ	Shrub	D			*					*	*				+++	N	Yellow
Salicaceae																			
Flacourtia flavescens Willd.	mp	SZ	Shrub	D			*	*									++	P	Yellow
Sapindaceae																			
Allophylus africanus P. Beauv.[#]	mp	GC-SZ	Shrub	D				*	*	*	*	*	*				+++	N	White
Blighia sapida K. D. Koenig[#]	mP	GC-SZ	Tree	D	*			*				*	*				+++	N	White
Blighia unijugata Baker	mP	GC	Tree	D												*	+++	N	Yellow
Cardiospermum grandiflorum Sw.	mp	GC	Liana	D					*	*	*	*					+	N	White
Paullinia pinnata L.[#]	mp	GC-SZ	Liana	D				*	*	*	*	*					+++	N	White
Sapotaceae																			
Vitellaria paradoxa C. F. Gaertn.[#]	mp	SZ	Shrub	D	*	*	*										+++	N	White
Solanaceae																			
Physalis angulata L.	Th	GC-SZ	Weed	D						*	*	*	*				+	N	Yellow
Talinaceae																			
Talinum triangulare (Jacq.) Willd.	np	GC	Weed	D				*	*	*	*	*	*				++	N-P	Pink
Verbenaceae																			
Stachytarpheta indica (L.) Vahl	np	GC	Bush	D								*	*	*	*		+	N	Violet
Vitaceae																			
Cissus populnea Guill. & Perr.[#]	mp	GC-SZ	Liana	D				*	*	*	*	*	*				+++	N-P	Yellow

Bt: Biological type; CT : Chorological type; MT : Morphological type; J: January; F: February; Mh: March; Ap : April; Ma: May; Je: June; Jy: July; At: August; S: September; O: October; Nv: November; Dc: December; FI: Foraging intensity; Nut: Nutrient; CF: color of flowers (corolla) ; Ch: Chamephyte ; Th: Therophyte; MP: megaphanerophyte; mP: mesophanerophyte ; mp: microphanerophyte; np: nanophanerophyte; Gr: geophyte rhizomatous; Hyd: hydrophyte; GC: Guinean and Congolese taxon; GC-SZ : Guinean and Congolese and Soudanese and Zambesi taxon; SZ : Sudanese and Zambesi taxon ; i : introduced taxon; GCW : endemic taxon in the forest block in western Togo; D: dicotyledon; M: monocotyledon; N: nectar; P: pollen; R: resin; Sj: Sweet juice; [#] : highly melliferous species

The monthly evolution of all 355 flowering species that have flowered is similar to that of honey taxa, with two flowering peaks, one in April and the other in September. The one of September is the most important (Figure 7). The specific richness of all flowering plants ranges from 45 species (12.68%) in February to 171 species (48.17%) in September. That of honey plants ranges from 20 species (15.87%) in February to 62 species (49.21%) in September. There is a positive correlation (r = 0.771, P = 0.003) between the change in monthly specific richness of all flowering species and that of the melliferous species.

The most significant flowering periods of honey plants vary according to the morphological type (Figure 8). Trees and shrubs (59 species) mostly flower in the off-season bushs, lianas and weeds (67 species). Indeed, many trees and shrubs gradually start to flower in November to reach the peak of flowering in April with 34 flowered species. The bushs have two peaks of flowering: between April and May with 8 species then between September and October (16 species). As for the weeds, they start flowering as early as March to reach their peak of flowering in September (21 species). Finally, lianas flower mostly between July and September.

Table-2: Distribution of melliferous species based on the foraging intensity and nutrient collected by bees

Nutrient provided	Class of species foraging intensity		
	Intensely foraged	Moderately foraged	Low-foraged
Nectar (%)	19,84	9,52	14,29
Pollen (%)	5,56	4,76	4,76
Nectar and pollen (%)	24,6	11,12	3,97
Sweet Juice (%)	0	0,79	0
Resin (%)	0,79	0	0
Species total number	64	33	29

Fig-4: *Crotum hirtus* L'Hérit. (Euphorbiaceae) foraged by a bee

Fig-5: *Adenia cissempeloides* (Planch. ex Hook.) Harms (Passifloraceae) foraged by a bee

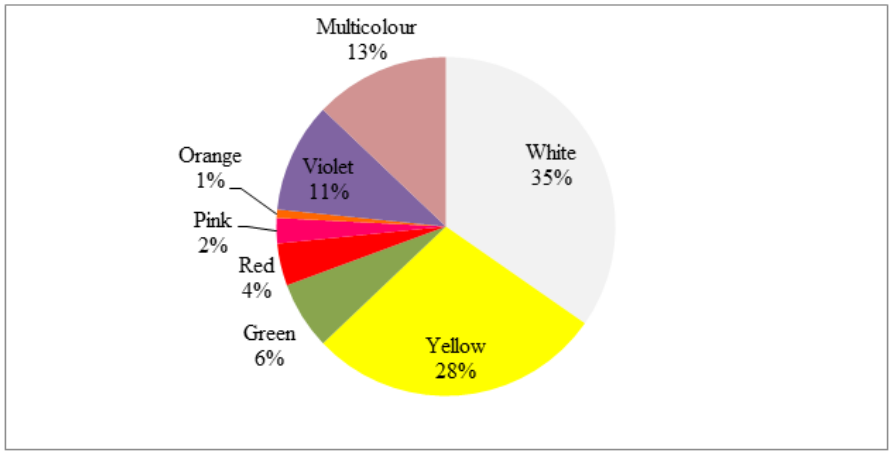

Fig-6: Melliferous plants distribution based on the color of the corolla

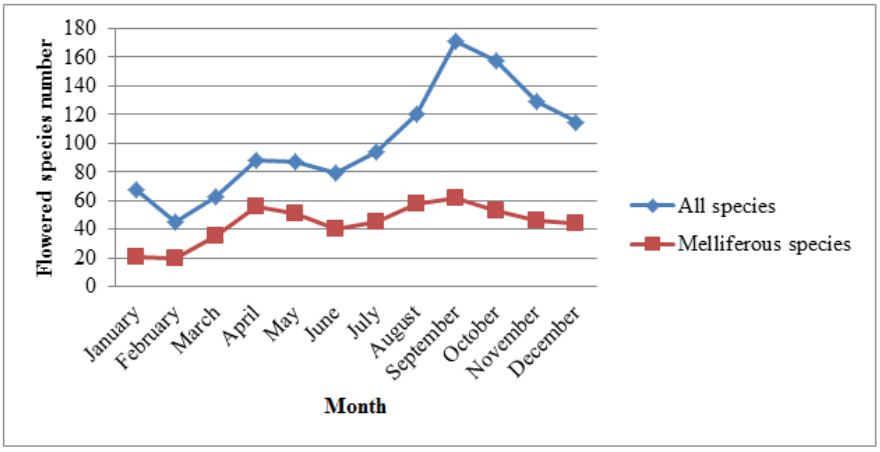

Fig-7: Monthly evolution of flowered species number around the apiary

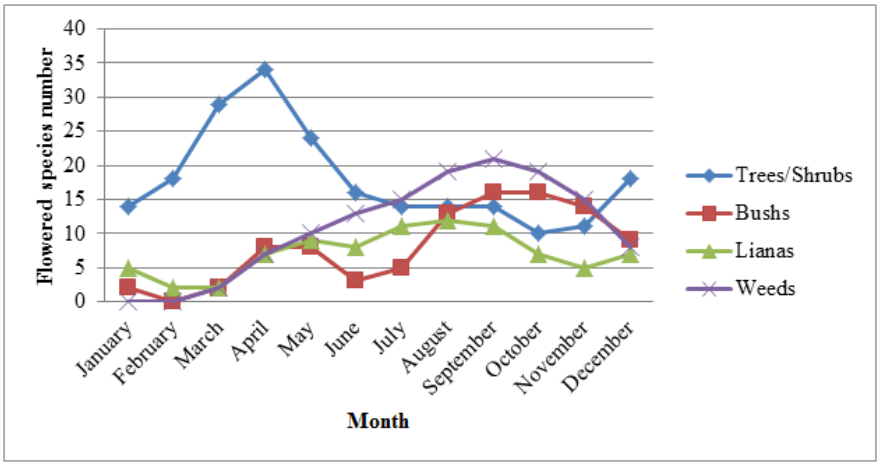

Fig-8: Monthly evolution of flowered melliferous species based on morphological type

DISCUSSION

The scientific interest for honey plants is very recent in Côte d'Ivoire. To our knowledge, this study is the third in terms of identification of honey plants, after the one carried out by [4] and [5]. On the other hand, it is the first in the sub-Sudanese savanna area, the two previous ones having been carried out in the forest-savanna transition zone of the Guinean domain. It allows extending the field of knowledge of honey plants in Côte d'Ivoire.

The number of melliferous species identified in this study (126 species) is almost like the one identified by [4] in the department of Dimbokro (128 species) through a similar methodology. On the other hand, it is lower than the 160 species listed by [5] in

Yamoussoukro area. This numerical superiority is due to a significant difference in the methodological approach. Indeed, in addition to the visual inventory, [5] considered melliferous species cited by farmers and beekeepers during an interview. In addition, the observations of these authors covered a radius of 3 km around the hives, against 1 km for this study.

The exclusive contribution of the present study to the knowledge of honey plants in Côte d'Ivoire was 59 species (31.55% of the identified melliferous flora) compared to the list of [4], 100 species by comparison to that of [5] and 54 species compared to the two lists at once. This brings to 305 melliferous species counted so far in Côte d'Ivoire through the visual field inventory method.

The rate of melliferous species which is 32.81% of the total flora of the environment shows a real selection of species to be foraged by bees. According to [22], this selection depends on the geographical area where these species are found. Indeed, some species, although present on the site studied in this case, were not considered as melliferous, contrary to the observations of [4]. These include *Ageratum conyzoides, Chromolaena odorata and Manihot esculenta.*

The predominance of Fabaceae, Asteraceae and Rubiaceae melliferous species constitutes an interesting floristic asset to produce honey in the study area in particular and in the sub-Sudanese region in general. In fact, the preponderance of species in these families is a general characteristic of this geographical domain [4, 15, 23, 25]. According to most of these authors, the great richness of Fabaceae in honey plants could be explained by their floral morphology [5, 26] which would offer bee's easy access to nutrients [27].

On the other hand, the abundance of melliferous species families such as Malvaceae, Lamiaceae and Sapindaceae is certainly due to the reclassification of several species in these families by the phylogenetic nomenclature used [17].

The melliferous flora is dominated by nectariferous species alone (43.65%) and mixed species (39.68%). In total, 83.33% of listed melliferous species provide bees with nectariferous floral resources. This value, obtained in the sub-Sudanese region, is higher than the 76% reported by [4] in the Guinean region and lower than the 85.4% obtained by [25] in the Sudanese region in Burkina. Thus, there is a gradient of increasing relevance regarding the proportion of nectariferous plants from the Guinean region to the Sudanese region. According to [28], the analysis of the visual inventory works of honey plants reveals a growing gradient of species richness in nectariferous plants from the Guinean region to the Sudanese region via Sudan and Guinea transition zone. This also confirms the observations of [22] and [29, 30] stating that nectar production depends, among other things, on climate and latitude.

Considering the flowering duration, the rate of foraging and the importance of the nectariferous species, it appears that the studied area is an environment with a high melliferous potential. Indeed, the melliferous potential of a region depends on its richness in nectariferous plants [31], the availability of the nectar of these plants for at least a month and a half and the foraging intensity of those ones carried out by bees [21].

The temporal evolution of the diversity of flowering plants reflects a permanent availability of floral resources throughout the year. This is of major importance for the success of beekeeping. However, the abundant flowering of trees and shrubs, over 93% of which have a nectariferous potential, covers the long dry season from November to March and part of the first rainy season, namely April [8]. Given their high production of nectar [15], the main honey raw material, trees and shrubs are believed to be the source of honeydew [23] during this period. As a result, beekeepers and honey gatherers in this area are harvesting honey from January until the start of the rainy season in April. Moreover [23] and [25], have identified two periods of honeydew in the Sudanese region of Burkina Faso with the most important coinciding with the abundant flowering of woody plants during the dry season. Thus, knowing trees and shrubs (woody plants) intense flowering period is an important indicator of beekeeping potential.

CONCLUSION

This study has shown that the sub-Sudanese area of Côte d'Ivoire has an important plant diversity allowing annual availability of food resources for bees. A total of 126 melliferous species have been identified in the department of Katiola. Trees and shrubs make up the majority of the 63 highly melliferous species that bloom mainly during the dry season (November-February). This season is the honeydew period in the area. Everything shows that the department of Katiola and, indirectly, the sub-Sudanese region is an ecosystem with high melliferous potential.

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