Plants foraged by bees in the Luki Biosphere Reserve (DR Congo)

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Abstract

Melliferous plants are plant species from which bees collect substances (nectar, pollen and resin) to feed themselves and elaborate their various productions. In order to update the knowledge of the main species of plants visited by bees in the transition zone of the Luki Biosphere Reserve in DRC, we conducted an inventory during 4 years (2017, 2018, 2019 and 2021) at a rate of 4 trips per year and 2 trips per season. The inventory was carried out by eye within quadrants of 1100 m^2 located in three habitats (savanna, forest and crop). The study showed the existence of a diversified flora made up of 35 foraged species, divided into 14 families. Among these, the most represented are Asteraceae (6 species), Fabaceae (5 species) and Rubiaceae (5 species). Moreover, bees were more attracted by white flowers (31.4%) followed by yellow flowers (20,0%).

Keywords: Bee, Honey plant, Luki Biosphere Reserve

INTRODUCTION

Melliferous plants are plant species from which bees collect substances (nectar, pollen and resin) to feed and to elaborate their productions. Thus, their daily activity on flowers is dependent on these substances (Suzo *et al.*, 2001). However, the knowledge of the melliferous flora and of the environmental factors influencing the quality and quantity of the harvested products is the basis of several services, such as beekeeping (Bakenga *et al.*, 2000).

Moreover, being the fundamental link of beekeeping, the melliferous flora is therefore an essential element in the conservation of bees and other pollinators (Sawadogo and Guinko, 2001; Nguemo *et al.*, 2008; Siendou *et al.*, 2013). Furthermore, accurate knowledge of the density, diversity, and flowering times of this melliferous flora allows one to determine the harvesting period and to estimate the importance of its future harvests of honey and other hive products (Bista and Shivakoti, 2001; Nombré, 2003 and Janssens *et al.*, 2006).

The modern beekeeping sector appears today as one of the activities that allow to increase the monetary income of the actors, to limit the destruction of forests and to generate a strong population of pollinating agents for the plant environment in general and for the crops in particular (Paterson, 2008).

Since it is recognized that 75% of cultivated plants of all species require bees for reproduction and that more than 80% of wild plant species are directly dependent on entomophilic pollination for fruit and seed production (Potts *et al.*, 2010), accurate knowledge of this flora will allow for good conservation of this apidofauna.

However, due to the high number of bee visits reported on species of the Fabaceae family in Luki Biosphere Reserve by Lubalega *et al.* (2021), the present study then strives to characterize the specific composition of the melliferous flora visited by bees for their management and conservation.

MATERIALS AND METHODS

Study area

The present study was conducted in the transition zone of the Luki Biosphere Reserve, which extends between 5°35' and 5°45' South latitude and between 13°07' and 13°15' East longitude (Figure 1). It is located 120 km from the Atlantic coast in the province of Central Kongo in the Democratic Republic of Congo with an altitude that varies between 150 and 500 m.

The Reserve is characterized by an Aw5 type climate according to the Koopen classification. It is further characterized by a rainy season that extends between October and May, and the major dry season between June, July and August, sometimes September. A small dry season is sometimes noticeable between December and February (Couralet *et al.*, 2013; Lubalega *et al.*, 2018).

The dry season lasts four months and is characterized by a slight drop in temperature and frequent morning fogs or drizzles, compensating for the soil water deficit. Precipitation is very erratic with an annual average of 1155 mm. Relative humidity remains high throughout the year, with a maximum in the dry season. The air saturation deficit is high in January, February, April and June. Annual insolation is low, at 32.1% of the astronomically possible insolation (Couralet *et al.*, 2013).

The Reserve has a non-forest flora containing grassy formations of probably climatic origin, but also of anthropic origin, as evidenced by the presence of crop weed species and ruderal species. The flora of shrubby savannahs is typically made up of xerophilous or mesophilous species adapted to the harshness and duration of the dry season (Lubini, 1997).

Spermatophytes constitute the predominant group of plant communities in the Reserve and represent 96.5% of the total specificity and the rest is composed of Pteridophytes which represent 3.5%. Within this forest flora, we distinguish the group of species of the primary

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forests and that of the secondary forests. The emerging trees belong to Annonaceae, Apocynaceae, Burseraceae, Caesalpiniaceae, Irvingiaceae, Meliaceae, Mimosaceae, Rubiaceae, Sapindaceae, Sapotaceae and Sterculiaceae. The species of secondary forests are generally evergreen or deciduous mesophytes (Lubini, 1997).

Data collection

The inventory of melliferous plants was carried out during 4 years (2017, 2018, 2019 and 2021) in the Luki Biosphere Reserve precisely in the transition zone and in 3 different habitats (forest, savanna and cultivation). According to the seasonality and for each year, 4 outings were carried out each year at a rate of two outings per season. In addition, due to the interval covering the maximum of the peak hours of bee activity, observations were conducted from 9:00 am to 4:00 pm (Fijen and Kleijn, 2017).

Direct observation of plants consisted of enumerating or identifying with the naked eye all plants that were visited by bees. However, visits were counted and flowers that were foraged by bees for at least two minutes were considered honey plants (Hamel and Boulemtafes, 2017).

Inventories were conducted in 6 quadrants of 1100 m^2 (110 m x 10 m) randomly selected due to the availability of flowering plants and installed in the three selected habitats. Thus, data collected also included color of foraged flowers, plant foraging rate, and ecological surveys (Thibaut, 2017). The plants visited were identified in the field by INERA/LUKI botanists and completed at the Herbarium of the University of Kinshasa/Department of Biology.

Ecological studies of melliferous species have focused on biological types, morphological types, leaf types, and diaspore types (Raunkiaer, 1934; Pauwels,1982; Lejoly & Mandango, 1982). All identified plants were classified into Clades, Orders, Families, Genera and Species (APG, 2016).

Data processing

Floristic diversity was assessed through species richness and family diversity. The maximum foraging rate (t) being 25%, three different classes of melliferous species were identified, taking into account the foraging intensity: Class A: weakly foraged species ($0 < t < 5\%$); Class B: moderately foraged species ($5 \leq t < 10\%$); Class C: intensely foraged species ($10 \leq t \leq 25\%$). The different graphs obtained in this work are made with the Excel 2016 software.

RESULTS

Floristic diversity analysis of plants foraged by bees

The melliferous species identified in this study are divided into 11 orders, 14 families, 35 genera and 35 species. Table 1 below presents the analysis of the specific diversity and their ecological characteristics.

From table 1, it appears that the family Asteraceae is the most visited with 6 species (17.1%), followed by Fabaceae and Rubiaceae with 5 species each (14.3%), followed by Acanthaceae, Amaranthaceae and Euphorbiaceae with 3 species each (8.57%), followed by Lamiaceae, Malvaceae and Poaeae with 2 species each (5.71%). The other families are represented with less than 5% of observations (Figure 2).

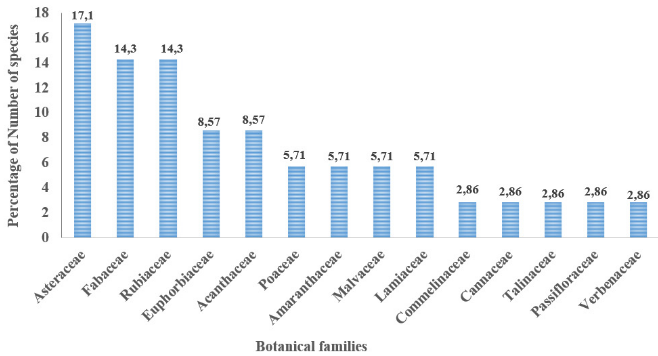

Figure 2: Families of honey plants visited by bees

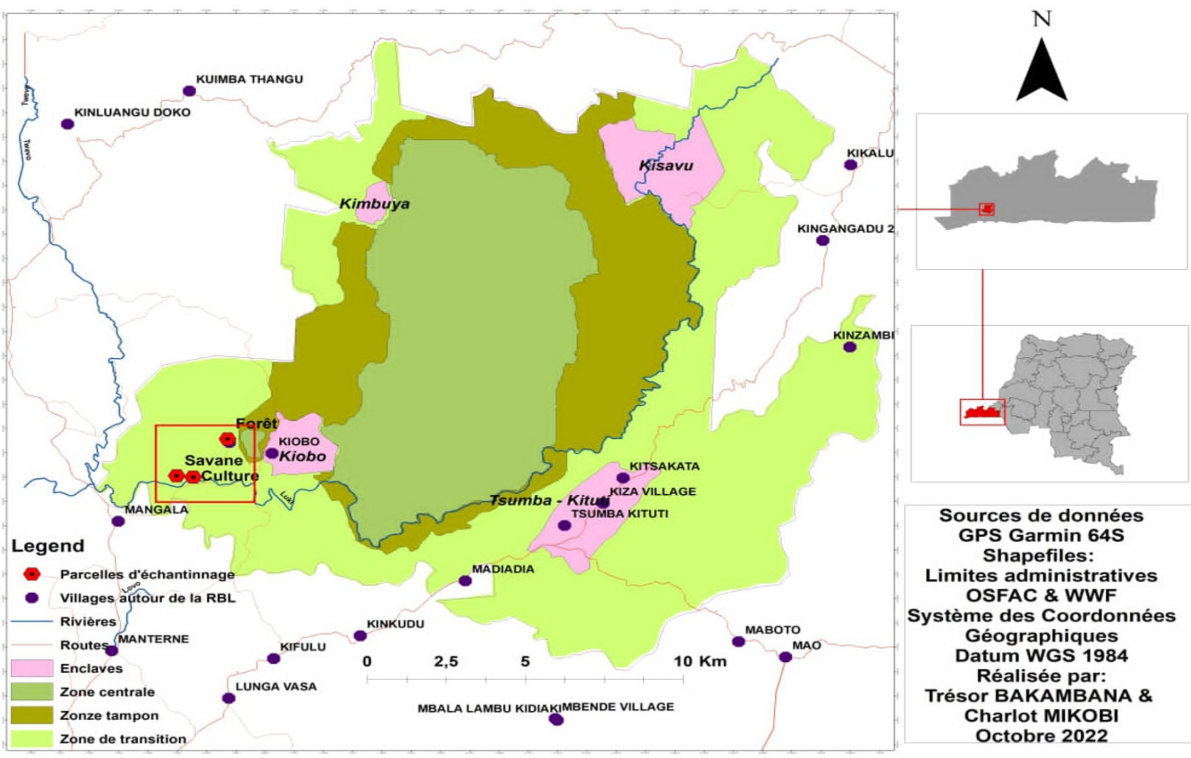

Figure 1: Map of the location of the study area

Table 1: Honey plants according to ecological characteristics

C:Clades O: Orders F: Families G: Genera	Ecological characteristics & chorology				
E: Species	**Biotope**	**MT**	**BT**	**LT**	**DT**
C.Angiospermes					
C.Monocotylédones					
C1.Monocotylédones					
C1.1.Commelinideae					
O1.Commelinales					
F1.Commelinaceae					
G1.Commelina					
ES1.*Commelina diffusa* Burm. F	Ru	Ha	Théro	Micro	Sarco
O2.Poales					
F2.Poaceae					
G2.*Panicum*					
ES2.Panicum sp.	Sav	Hv	Hémicrypt	Micro	Scléro
G3.*Zea*					
ES3.*Zea mays* L.	Cult	Ha	Hémicrypt	Micro	Scléro
O3.Zingiberales					
F3. Cannaceae					
G4.Canna					
ES4.*Canna indica* L.	Cult	Hv	Géophy	Méso	Sarco
C2.Angiospermes					
C2.1. Magnoliideae					
O4.Caryophyllales					
F4. Talinaceae					
G5.Talinum					
ES5.Talinum triangulare (Jacq) Wild	Ru	Ha	Chamae	Méso	Scléro
F5.Amaranthaceae					
G6.Celosia					
ES6 *Celosia trigyna* L.	Ru	Ha	Théro	Micro	Sarco
G7.Alternanthera					
ES7. *Alternanthera brasiliana (L.) Kuntze*	Ru	Hv	Chamae	Lepto	Scléro
C3. Angiospermes					
C3.1Superrosidées					
O6.Fabales					
F6. Fabaceae					
G8.*Calopogonium*					
ES8.*Calopogonium mucunoides* Desv.	Ru	Lia	Chamae	Méso	Ballo
G9.Desmodium					
ES9. *Desmodium mauritianum*	Ru	S/arb	Chamae	Méso	Ballo
G10.*Psophocarpus*					
ES10.*Psophocarpus scandens* (Endl.) Verdc.	Cult	Lia	Chamae	Méso	Ballo
G11.Pueraria					
ES11. *Pueraria phaseoloides* (Roxb.) Benth. var. javanica (Benth.) Bak	Cult	Ha	Chamae	Méso	Ballo
G12.Mimosa					
ES12.*Mimosa pudica* L.	F	Hv	Chamae	Lepto	Desmo
O7.Malpighiales					
F7.Euphorbiaceae					
G13.Croton					
ES13. Croton hirtus L'her.	Sav	Ha	Théro	Méso	Sarco
G14.Euphorbia					
ES14. *Euphorbia hirta* L.	Ru	Ha	Théro	Nano	Ballo
G15.*Manihot*					
ES15. *Manihot esculenta* Crantz	Cult	arb	Phanéro	Méso	Sarco

Table 1 (suite): Honey plants according to ecological characteristics

O8.Malvales	Biotope	MT	BT	LT	DT
F8.Malvaceae					
G16.*Sida*					
ES16.*Sida rhombifolia* L.	Ru	S/arb	Chamae	Micro	Ballo
G17.Waltheria					
ES17.*Waltheria indica* L.	Sav	S/arb	Chamae	Méso	Sarco
F9.Passifloraceae					
G18.Passiflora					
ES18.*Passiflora edulis* Sims	Cult	Lia	Phanéro	Méso	Sarco
C4.Angiospermes					
C4.1.1.Dicotylédones vraies					
C4.1.1.2.Superrosideae					
C4.1.1.3.Fabideae					
C5.Dicotylédones vraies					
C5.1.Lamideae ou Euastérideae					
O9.Gentianales					
F10.Rubiaceae					
G19.Geophyla					
ES19.*Geophyla obvallata* (Schumach.) F.Didr.	Ru	Ha	Théro	Micro	Sarco
G20.Mitracarpus					
ES20.*Mitracarpus villosus* (Sw.) DC .	Ru	Ha	Théro	Micro	Sarco
G21.Oxyanthus					
ES21.*Oxyanthus speciosus* DC.	F	arb	Phanéro	Méso	Sarco
G22.*Oldenlandia*					
ES22.*Oldenlandia corymbosa* L.	Ru	Ha	Théro	Nano	Sarco
G23.Spermacoce					
ES23.*Spermacoce latifolia* Borkh.	Ru	Ha	Théro	Nano	Sarco
C6.Asterideae					
C6.1.Lamideae					
C6.1.1Superastéridées					
C61.1.1.Asteridéae					
C6.1.1.2.Lamideae					
C6.1.1.3.Campanulideae					
O10.Asterales					
F11.Asteraceae					
G24.Ageratum					
ES24. *Ageratum conyzoides* L.	Ru	Ha	Théro	Micro	Pogo
G25.Synedrella					
ES25.*Synedrella nodiflora* L.	Ru	Ha	Théro	Micro	Pogo
G26.*Bidens*					
ES26.*Bidens pilosa* L.	Ru	Ha	Théro	Micro	Desmo
G27.Emilia					
ES27.*Emilia coccinea* Sims	Ru	Ha	Théro	Micro	Desmo
G28.Corchorus					
ES28.*Corchorus aestruans*	Ru	Hv	Chamae	Micro	Pogo
G29.*Chromolaena*					
ES29.*Chromolaena odorata* (L.)	Ru, Jach.	arb	Chamae	Méso	Pogo
F12.Acanthaceae					
G30.*Asystasia*					
ES30. *Asystasia gangetica* (L.) subsp. micrantha	Ru	Ha	Chamae	Méso	Ballo
G31.Dicliptera					
ES31.*Dicliptera verticillata* (Forssk.) C. Christ.	Ru	S/arb	Chamae	Méso	Scléro
G32.Justicia					
ES32.Justicia insularis T. Anders.	Ru	Ha	Chamae	Méso	Ballo
O11.Lamiales					
F13.Lamiaceae					
G33.Ocimum					
ES33.*Ocimum basilicum* Lam.	Ru	Ha	Théro	Micro	Desmo
ES34. *Ocimum gratissimum* L.	Cult	S/arb	Chamae	Méso	Scléro
F14.Verbenaceae					
G35.Lantana					
ES35.*Lantana camara* L.	F	Arb	Phanéro	Méso	Sarco

Moreover, within the 35 species recorded, *Spermacoce latifolia* was the species most visited by bees in this Reserve with 642 visits out of 4843 or 13.3% of total visits. It was followed by *Justicia insularis* and *Pueraria phaseoloides* with 445 and 409 visits respectively, that is 9.19% and 8.46% of the total visits (Figure 3).

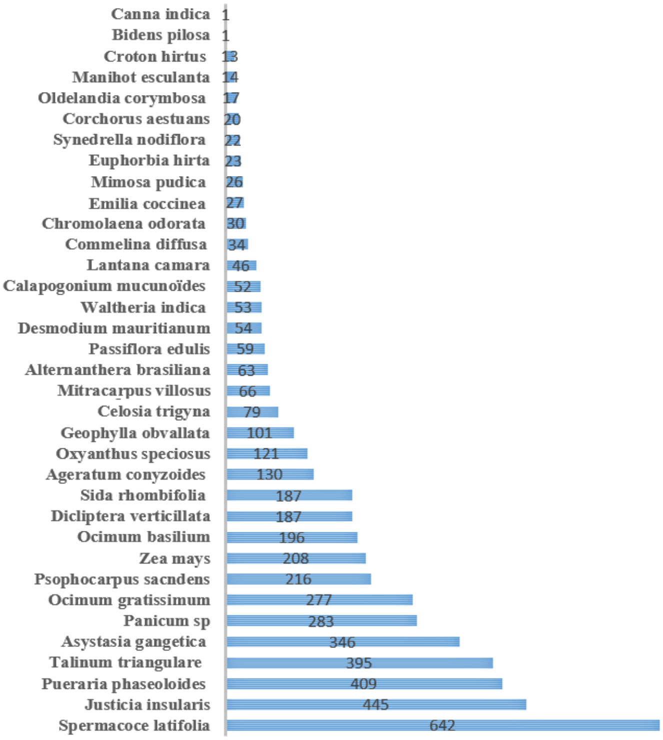

Figure 3: Species of honey plants visited by bees

Analysis of ecological characteristics

Concerning the ecological characteristics of the species inventoried, figure 4 shows that champhytes and therophytes were in the majority with 15 and 14 species respectively (42.7% and 37.1%). They are followed by phanerophytes with 4 species (11.4%).

The distribution according to the morphological type shows that the annual grasses are the most represented (51.4%) followed by sub-shrubs and perennial grasses in exæquo with 14.3%. Shrubs and lianas are the least represented.

The analysis of leaf types as presented in figure 4 shows a high abundance of mesophylls with 17 species (48.6%) followed by microphylls with 14 species (37.1%). The other leaf types are poorly represented.

Considering the types of diaspores, the result found shows a remarkable preponderance of Sarcochores species with 13 species (37.1%) followed by Ballochores and Sclerochores with respectively 8 and 6 species (i.e. 22.9% and 17.1%). The other types of diaspores are poorly represented.

According to this study, it appears that the melliferous resources of the study area are mainly composed of a preponderant flora of ruderal species with 22 species (or 62.9%) of the plants recorded. The remainder is composed of crop plants (7 species, or 20%), savannah plants with 3 species (8.57%) respectively in savannah and forests (Figure 4).

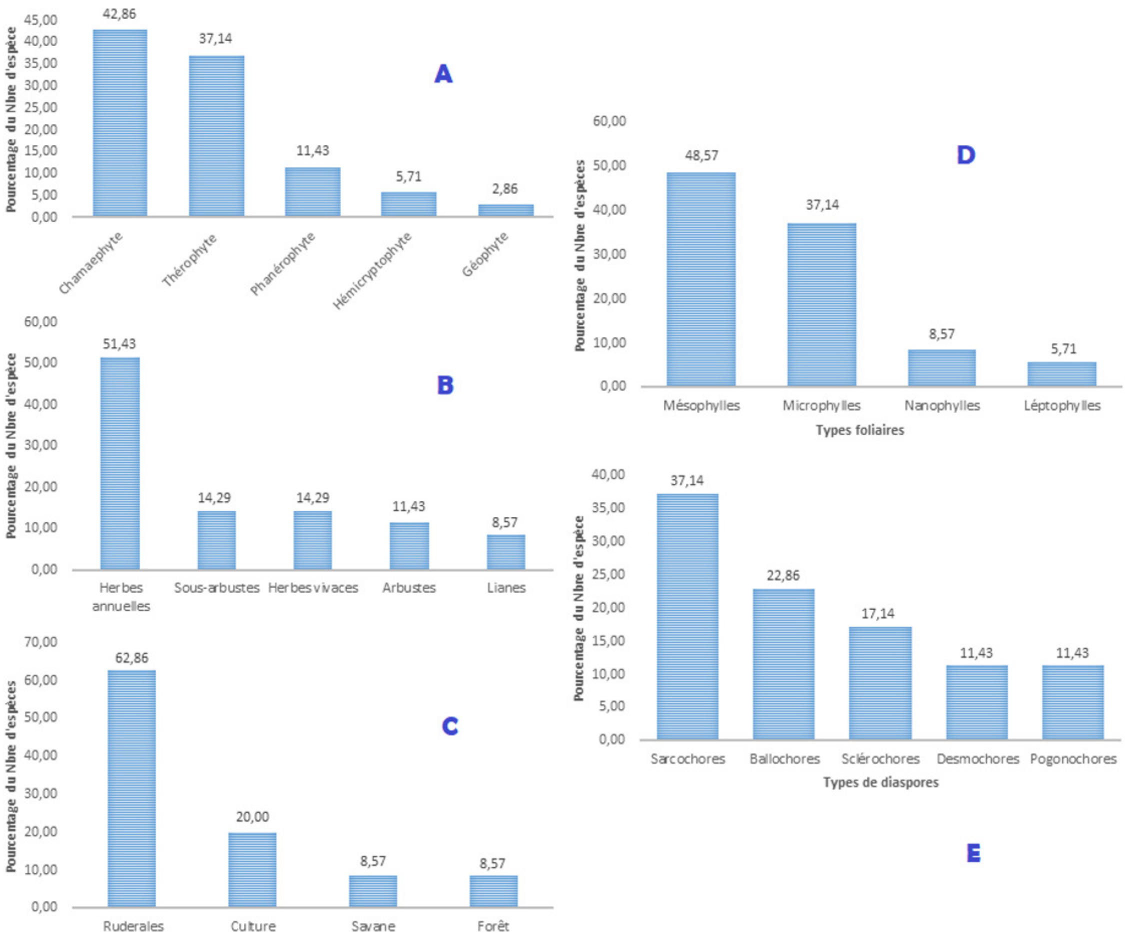

Figure 4: Distribution of honey plants according to: A: Biological types; B: Morphological types; C: Biotope types; D: Leaf types; E: Diaspora types

Analysis of foraging characteristics

Table 2 shows the characteristics related to bee foraging.

From table 2, it is clear that the medium and intensive foraging species were in the majority with 13 species respectively, or 37% of observations. Weakly foraged species were less represented with 9 species (26%) (Figure 5).

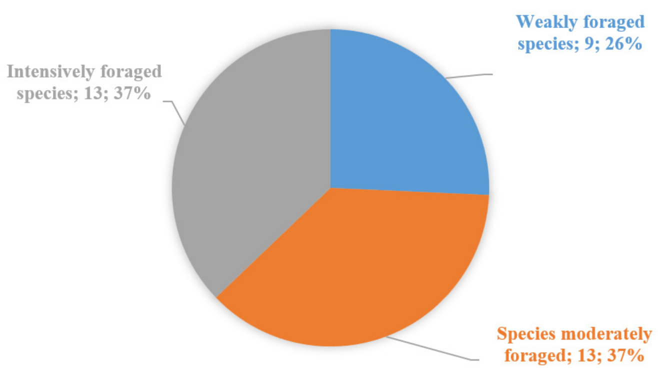

Figure 5: Distribution of species according to foraging intensity

Color of the flowers of the plants foraged by the bees

Considering the colors of the flowers of the melliferous flora, the flowers of white color are the most visited by the bees with 31,4% (Figure 6). They are followed by those of yellow color with 20,0%. Then come the blue flowers with 5.71%. The other flowers were visited with an equal proportion of 2.86%.

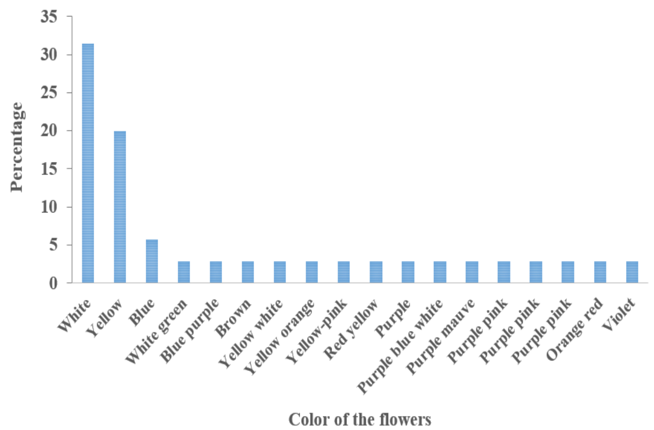

Figure 6: Distribution of the colors appreciated by the bees

DISCUSSION

The literature on the inventory of melliferous plants in the Luki Biosphere Reserve in particular is still limited for the moment, except for the work presented in 2021 by Lubalega *et al.* (2021). In order to complete the data related to the knowledge of the melliferous flora in this Reserve, the present study focused on knowing the melliferous flora and allowed to count 35 species. This specific melliferous richness is lower than that recorded in the Sudano-Guinean zone in Cameroon (41 species), in the classified forest of the Kouandé hills in northwest Benin (86 species) and in the classified forest of Lama in the Guinean zone (92 species) (Yédomonhan, 2004; Ahouandjinou *et al*,. 2017). This difference would be due to the influence of a number of factors: ecological environment and size of the area.

In terms of volume, the most important works are those of Guinko *et al.* (1992) who recorded 159 species in the western region of Burkina Faso and 147 species in Bukavu and its surroundings in DR Congo (Bakenga *et al.*, 2000). This clear numerical difference can be explained by the floristic composition of the stations and the foraging ethology of the bees. It appears from these results that bees make a real selection of species which is notably influenced by the floristic composition, the phenology of the melliferous species and the intrinsic characteristics of the flower, namely: the color of the flower, the odor emanating from the flower, the floral conformation and the attractiveness of the nectar and/or the pollen produced by the flower.

Table 2: Analysis of foraging aspects

Especies	RA	Color of the flowers	FR	CI
Alternanthera brasiliana	63	White	17,2	C
Celosia trigyna	79	White	1,56	A
Chromolaena odorata	30	White	12,5	C
Croton hirtus	13	White	9,38	B
Geophylla obvallata	101	White	12,5	C
Mitracarpus villosus	66	White	4,69	A
Ocimum basilium	196	White	1,56	A
Ocimum gratissimum	277	White	6,25	B
Oldelandia corymbosa	17	White	10,9	C
Oxyanthus speciosus	121	White	1,56	A
Spermacoce latifolia	642	White	12,5	C
Passiflora edulis	59	White green	6,25	B
Calapogonium mucunoïdes	52	Blue	14,1	C
Commelina diffusa	34	Blue	1,56	A
Psophocarpus sacndens	216	Blue mauve	12,5	C
Panicum sp	283	Browns	3,13	A
Corchorus aestuans	20	Yellow	7,81	B
Euphorbia hirta	23	Yellow	17,2	C
Manihot esculanta	14	Yellow	6,25	B
Sida rhombifolia	187	Yellow	9,38	B
Synedrella nodiflora	22	Yellow	6,25	B
Waltheria indica	53	Yellow	3,13	A
Zea mays	208	Yellow	6,25	B
Bidens pilosa	1	Yellow white	6,25	B
Emilia coccinea	27	Yellow orange	17,2	C
Lantana camara	46	Yellow pink	9,38	B
Canna indica	1	Yellow red	14,1	C
Desmodium mauritianum	54	Mauve	6,25	B
Ageratum conyzoides	130	Mauve blue white	12,5	C
Pueraria phaseoloides	409	Mauve violet	23,4	C
Mimosa pudica	26	Pink mauve	7,81	B
Talinum triangulare	395	Pink purple	6,25	B
Justicia insularis	445	Pink violet	21,9	C
Dicliptera verticillata	187	Red orange	4,69	A
Asystasia gangetica	346	Violet	3,13	A

RA: relative abundance, FR: foraging rate, CI: foraging intensity class (A: lightly foraged, B: moderately foraged, C: intensely foraged)

The analysis of family diversity shows that the 35 melliferous species identified in the present study are divided into 14 families with a predominance of Asteraceae followed by Fabaceae and Rubiaceae as found by Hamel and Boulemtafes (2017). Our results corroborate the work of Lubalega *et al.* (2021) who identified 31 families with a predominance of Fabaceae. Furthermore, the work of Bakenga *et al.* (2000) in Bukavu and its surroundings noted a predominance of Asteraceae with 39 families recorded.

The temporal evolution of the diversity of flowering plants reflects a permanent availability of floral resources throughout the year (Chahma and Djebar, 2008). Hamel and Boulemtafes (2017) found in northeastern Algeria a dominance of perennial plants represented by phanerophytes followed by therophytes while the present study presents a strong dominance of chamaephyes followed by therophytes which are the result of a degradation of the vegetation cover following disturbances of the biotope (Barbéro *et al* 1990).

In relation to the morphological types of melliferous plants, our results are broadly consistent with those found in other areas (Bakenga *et al*, 2000; Ricciardelli, 1998; Tchuenguem*et al*, 1997; Nguemo *et al*., 2004) with much larger numbers of plants, respectively in the Mediterranean zone, in the west of Cameroon and the Bukavu region in the Democratic Republic of Congo, grasses are the most represented. This clearly indicates that this flora is highly anthropized.

In spite of the selection of honey species by bees, as discussed by Nombré (2003), floral availability may reflect a high availability of nutrients for bees. However, melliferous plants are mainly spontaneous species considered as an important food source for bees (Louveau, 1968). This explains the high abundance of ruderal species in the study area, which shows that the vegetation in the study area is threatened by anthropogenic activities, resulting in anthropized vegetation.

Regarding the analysis of leaf types, we observe an abundance of mesophyll species with 17 species (48.6%). This predominance of mesophyll species in the Luki Biosphere Reserve indicates the predominance of heliophilic and forest species. Hence the greater proportion of Rubiaceae in the study area, a family of pioneer species that colonize degraded areas, suggests a clear forestry trend.

We also observed a strong predominance of sarcochorous species according to the types of diaspores with a procession of 13 species (37.1%). The abundance of Zoochores is justified by the fact that animals, including humans, are the greatest disseminators of all species in our study area. Indeed, Rubiaceae species establish themselves in the evolving understory and benefit from the dispersal of their seeds by local fauna, including bees (Nombré, 2003). Incursion of bushpig, duiker or Cephalophys (antelope) is common in the vicinity of the Inera-Luki station. Birds and flying mammals (bats) also participate in this dissemination, contributing to the extension of the forest. Environmental factors can limit the natural regeneration process in Mayombe.

According to Hamel (2013), the analysis of flower color of honey plants is related to the richness of the flora of the ecological environment. However, this study showed a large variability of colors in the honey flora. Our results corroborate with the work of Bakenga *et al.* (2000), Nguemo *et al.* (2004), and Hamel and Boulemtafes (2017), who in turn find significant flower color diversity in the honey flora.

While overall we found the same types of flower colors in the Luki Biosphere Reserve, bees clearly prefer the color white (31.4%) and yellow (20,0%). These results corroborate those of Nguemo *et al.* (2004), Hamel and Boulemtafes (2017) and Iritie *et al.* (2014) and Ahouandjinou *et al.* (2017). However, our results nevertheless contradict the work done in Bukavu by Bakenga *et al.* (2000) who believe that bees would be more attracted to blue, beige and yellow colors. This difference could be explained by the composition of the species present on the study site or by the preference of bees in terms of food. Thus, according to Leong and Thorp (1999) in Lukoki *et al.* (2021), the colors would be a mimetic indication of the accessibility of nectaries and thus the availability of food resources.

CONCLUSION

The study of the melliferous plants of the Luki Biosphere Reserve allowed us to identify 35 species foraged by bees, divided into 14 families, with a predominance of Asteraceae, Fabaceae and Rubiaceae. Moreover, bees were more attracted by white flowers with a predominance of 31.4% followed by yellow color with 20,0%. Also, the study notes that ruderal species were in the majority alongside annual grasses and chamephytes.

However, in the context of strong human pressure in this Reserve, which has negative impacts on the environment and natural resources, we are aware that the inventory carried out is far from being exhaustive and should be continued in order to characterize in a general way the plant species visited by bees and the possible change that can occur in this selection.

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