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

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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%).

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 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 m² (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).

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).

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).

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).

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%.

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.

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; Tchuenguemet 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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