



RESEARCH PAPER

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Temporal availability of floral resources for the honey bee (*Apis mellifera*) in a forest ecosystem in the sudanian zone of Côte d'Ivoire: The case of Badenou classified forest

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ABSTRACT

The development of beekeeping in the buffer zones of protected forests can involve local communities in the sustainable management of these ecosystems. However, successful beekeeping requires knowledge of the honey plants present in the apiaries' environment and their flowering periods. This study aimed to determine the species richness of honey plants in the Badenou classified forest and the temporal availability of their floral resources. Data were collected in the Badenou classified forest using floristic inventories and observations of bee foraging activity conducted monthly during one year. A total of 112 honey plant species were recorded, corresponding to 77.24% of the 145 species that flowered. The species richness of flowering honey plants varied over time. It was lowest with 16 species in December and highest with 46 species in September. The trends in species richness of woody honey plants and herbaceous honey plants show a highly significant negative linear correlation ( $r = -0.644$  and  $p = 0.024$ ). Floral resources from honey plants were available year-round, with two periods of abundance: one corresponding to the abundant flowering of woody species during the dry season and the other to the abundant flowering of herbaceous species during the wet season. These characteristics of the honey plants in the Badenou classified forest are favourable to the development of modern beekeeping. However, an analysis of physicochemical and organoleptic characteristics of honey produced could be conducted to identify any distinctive properties that could be used to enhance its commercial value.

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## INTRODUCTION

Beekeeping is the branch of agriculture that consists of raising honeybees to harvest hive products, mainly honey but also beeswax, royal jelly, pollen, propolis, and bee venom.

Beekeeping is a strategic tool in the sustainable management of national parks and classified forests for several reasons. First, the abundance of plants whose flowers are foraged by bees in the apiaries' environment is essential to the success of beekeeping (Bouzebda *et al.*, 2018).

As beekeeping requires relatively few financial, material, and human resources, it can easily be integrated with other agricultural activities (Sokemawu, 2016; Owuor *et al.*, 2022; Dusengimana and Maake, 2024). Secondly, through the role played by foraging bees in crop pollination, beekeeping has a positive impact on agricultural yields (Fohouo *et al.*, 2009; Yédomonhan and Akoègninou, 2009; Djonwangwé *et al.*, 2011; Adamou and Fohouo, 2014; Tchindebe and Fohouo, 2014; Vaziritabar *et al.*, 2015; Egono *et al.*, 2018; Pharaon *et al.*, 2019; Ambreen *et al.*, 2021). Through the pollination of forest plants, beekeeping contributes to the regeneration of forest ecosystems. In addition, beekeeping in the buffer zones of national parks and classified forests is a form of sustainable management of these ecosystems, generating income for local communities while reducing their pressure on natural resources. Finally, it constitutes a tool for community-based monitoring and forest fire prevention. Beekeepers, who are often present in the forest, act as sentinels, reporting illegal activities such as poaching and illegal timber harvesting, and fighting fires to protect their apiaries. Thus, the development of sustainable beekeeping in the buffer zones of national parks and classified forests allows local communities' participation in the sustainable management of natural resources, while preserving the integrity of these ecosystems.

However, knowledge of the honey plants present in the environment around apiaries and the periods

when their floral resources are available is essential for the development of sustainable beekeeping (Dongock *et al.*, 2004; Népide and Tchuenguem, 2016; Fohouo *et al.*, 2018). Indeed, the quantity and quality of hive products depend on the nature and abundance of honey plants (Dongock *et al.*, 2008; Balagueman *et al.*, 2017). Knowing the seasonal availability of floral resources for honey plant species makes it possible to identify periods of abundant flowering that can lead to honey accumulation in hives (Yédomonhan *et al.*, 2012). It is in this context that this study was conducted in the Badenou classified forest. It aims to determine the species richness of honey plants and the temporal availability of their floral resources with a view to the development of modern beekeeping.

## MATERIALS AND METHODS

### Study area

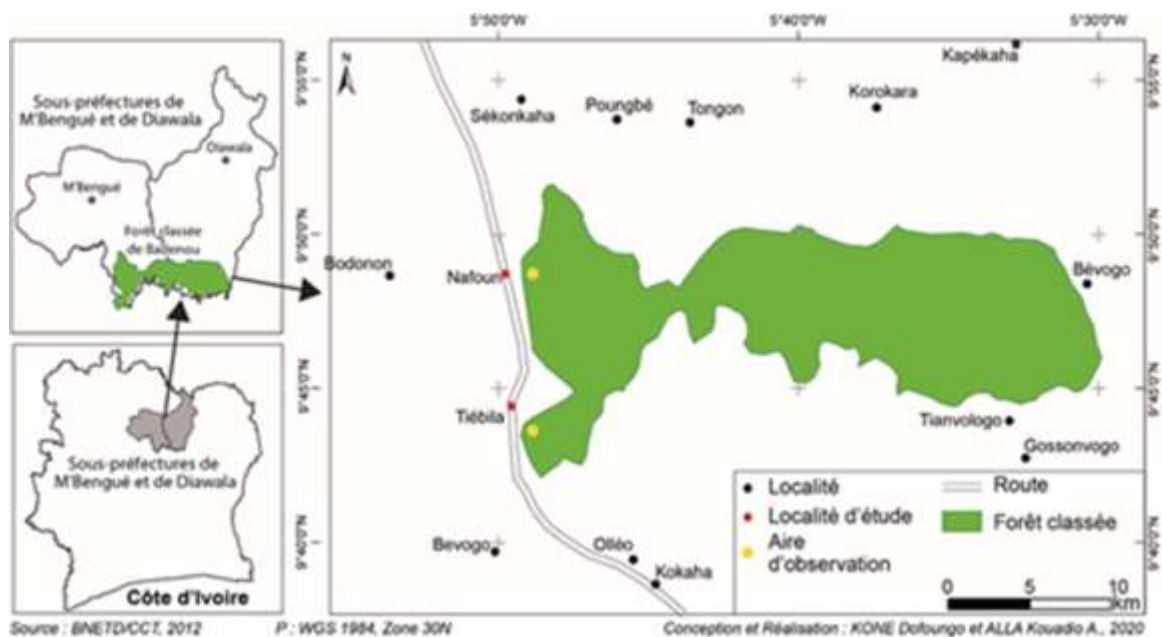
The study was conducted in the Badéno classified forest, located in northern Côte d'Ivoire between longitudes 5° 32' 06" and 5° 49' 67" West and latitudes 9° 41' 63" and 9° 51' 63" North (Yaokokoré-Béibro *et al.*, 2010). Covering an area of 26,980 ha, this forest is situated in the southeast of the M'bengué subprefecture and the south of the Diawala subprefecture.

The floristic inventories were conducted in the peripheral zone of this classified forest, near the villages of Tiébila and Nafoun (Fig. 1). The Badenou classified forest is located in the Sudanese phytogeographic sector of Côte d'Ivoire. Thus, its natural vegetation consists of tree and shrub savannas, wooded savannas, open forests, and riparian forests along watercourses (Guillaumet and Adjanohoun, 1971). The climate is dry tropical, with a seven-month dry season lasting from November to May and a rainy season from June to October, with peak rainfall in August (Soro *et al.*, 2018).

plant survey plots; – a 100-meter measuring tape and stakes for marking the plot borders; – a set of plant cutters, for collecting plant samples to be sent to the herbarium; – straps, cardboard and newspaper for

pressing and drying the collected plant samples; – floristic survey forms for recording observations; – a binocular magnifying glass and old plant specimens

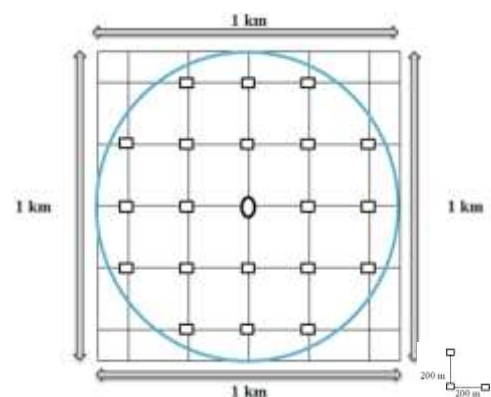
stored in the herbarium of the Swiss Scientific Research Center in Côte d'Ivoire for plant identification in the laboratory.



**Fig. 1.** Location of the study area

### Biological and technical materials

For this study, both biological and technical materials were utilized. The biological materials comprised the plant species identified within the Badenou classified forest and the honeybees (*Apis mellifera*) observed foraging on flowers. The technical materials included ten Kenyan-style hives arranged into two apiaries to accommodate bee colonies and increase the likelihood of observing foraging bees within the study areas. A Global Positioning System (GPS) was used to locate observation sites and floristic survey plots, while a 100-m measuring tape and stakes were employed to demarcate plot boundaries. Plant samples were collected using pruning tools and subsequently pressed and dried with straps, cardboard, and newspaper before being sent to the herbarium for identification. Floristic survey forms were used to record field observations. In addition, a binocular magnifying lens and reference plant specimens preserved in the herbarium of the Swiss Scientific Research Center in Côte d'Ivoire were used to facilitate laboratory identification of plant species.



○ Apiary □ Floristic survey plots

**Fig. 2.** Distribution of floristic survey plots at an inventory site

### Data collection device

To collect data, two observation areas, each with a radius of 0.5 km, were delineated in the peripheral zone of the classified forest, near the villages of Nafoun and Tiébila (Fig. 2). The size of each observation area was 78.5 ha. Thus, the total size of the two observation areas was 157 ha. In each observation area, 20 rectangular plots measuring 20 m × 25 m (500 m<sup>2</sup>) were established, spaced 200 m from each other (Fig. 2).

### Floristic inventory and identification of plant species

All woody and herbaceous plants found within the floristic survey plots were inventoried. Plant species were identified with the assistance of a botanical taxonomist from the Swiss Center for Scientific Research in Côte d'Ivoire. Plant samples were collected and sent to the Center's herbarium for identification. These identifications were made by comparing collected samples with reference specimens preserved in the herbarium. The botanical nomenclature of the species used is that of the online database of African plants (<http://www.ville-ge.ch/musinfo/bd/cjb/africa/>). The APG IV (2016) botanical classification was adopted for grouping species within families. As for the determination of morphological types of the species, this was carried out using the works of Aké-Assi (2001 and 2002) and Chatelain *et al.* (2011).

### Inventory of flowering plants and honey plants

Flowering plants and honey plants were inventoried using direct field observation. Each floristic survey plot was visited monthly during a one-year period. During these monthly visits, all flowering plants and those visited by bees were recorded. Observations were made with the naked eye for herbaceous plants and shrubs, or using binoculars for trees and shrubs.

Honey plants are plants whose flowers were visited by foraging bees to collect pollen and/or nectar. When foraging bees landed on flowers and made movements with their hind legs that led to the formation of visible pollen balls in their baskets, the plant was classified as polliniferous (Yédomonhan *et al.*, 2009). When foraging bees inserted their proboscis into flowers to suck up nectar, the plant was considered nectariferous (Dongock *et al.*, 2004). When bees collected both pollen and nectar from the same plant, it was classified as nectaropolliniferous (Iritié *et al.*, 2014).

### Data treatment and analysis

Data extracted from the floristic survey forms were entered and organized using Microsoft Excel 2016. Descriptive analyses were performed using pivot tables to determine the species richness of flowering

plants and honey plants, the flowering rate of plant species, the selection rate of flowering species by *Apis mellifera*, and the monthly variations in the numbers of flowering species and honey plant species.

To examine temporal relationships among the studied variables, Pearson correlation analyses and simple linear regression models were conducted. These analyses assessed the relationships between the number of flowering herbaceous species and herbaceous species visited by bees, the number of flowering woody species and woody species visited by bees, the total number of flowering species and the total number of species visited by bees, the number of flowering herbaceous species and flowering woody species, and the number of herbaceous honey plant species and woody honey plant species.

The strength and direction of these relationships were evaluated using Pearson's correlation coefficient ( $r$ ), while the coefficient of determination ( $R^2$ ) was used to estimate the proportion of variation in the dependent variable explained by the independent variable. Statistical significance was assessed at the 5% probability level ( $p \leq 0.05$ ). All analyses were performed in Microsoft Excel 2016 after verifying the normality of the data distribution.

## RESULTS

### Flowering ratio of plant species

Flowering was observed in 145 plant species out of a total of 243 species surveyed (Table 1). Thus, the flowering ratio was 59.67% for all plant species recorded. The flowering ratio was 52.38% for herbaceous species and 70.83% for woody species.

### Selection ratio of plant species by *Apis mellifera*

Monitoring of the foraging activity of *Apis mellifera* identified 112 species of honey plants (Table 2). This corresponds to a selection ratio of 77.24% for all flowering plant species. The selection ratio was 71.43% for herbaceous species and 83.82% for woody species. The list of plant species visited by *Apis mellifera* is presented in Table 3.

**Table 1.** Flowering ratio of recorded plant species

Plant categories	Number of species recorded	Number of flowering species	Flowering ratio (%)
Herbaceous plants	147	77	52,38
Woody plants	96	68	70,83
Total	243	145	59,67

**Table 2.** Species selection ratio by *Apis mellifera*

Plant categories	Number of flowering species	Number of foraged species	Selection ratio (%)
Herbaceous plants	77	55	71,43
Woody plants	68	57	83,82
Total	145	112	77,24

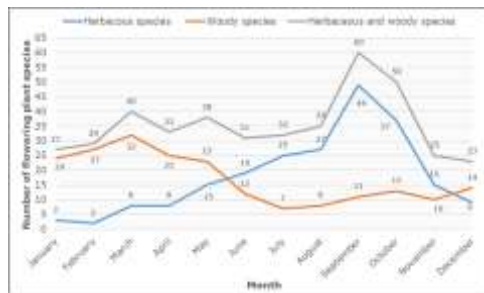
**Table 3.** List of honey plant species recorded

Species	Family	Morphology	Interest for bees
<i>Acacia albida</i>	Fabaceae	Tree	Nectar
<i>Acacia dudgeonii</i>	Fabaceae	Small tree	Nectar
<i>Acacia polyacantha</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Aeschynomene afraspera</i>	Fabaceae	Herb	Pollen
<i>Afzelia africana</i>	Fabaceae	Tree	Nectar/Pollen
<i>Ageratum conyzoides</i>	Asteraceae	Herb	Pollen
<i>Allophylus africanus</i>	Sapindaceae	Small tree	Nectar/Pollen
<i>Anacardium occidentale</i>	Anacardiaceae	Tree	Nectar
<i>Andropogon gayanus</i>	Poaceae	Herb	Pollen
<i>Andropogon schirensis</i>	Poaceae	Herb	Pollen
<i>Annona senegalensis</i>	Annonaceae	Shrub	Nectar/Pollen
<i>Anogeissus leiocarpa</i>	Combretaceae	Small tree	Nectar/Pollen
<i>Antidesma venosum</i>	Phyllanthaceae	Small tree	Nectar/Pollen
<i>Aspilia africana</i>	Asteraceae	Herb	Pollen
<i>Aspilia rudis</i>	Asteraceae	Herb	Pollen
<i>Borreria filifolia</i>	Rubiaceae	Herb	Nectar
<i>Borreria intricans</i>	Rubiaceae	Herb	Nectar
<i>Borreria latifolia</i>	Rubiaceae	Herb	Nectar
<i>Borreria ruelliae</i>	Rubiaceae	Herb	Nectar
<i>Borreria scabra</i>	Rubiaceae	Herb	Nectar
<i>Borreria verticillata</i>	Rubiaceae	Herb	Nectar/Pollen
<i>Brachiaria jubata</i>	Poaceae	Herb	Nectar/Pollen
<i>Bridelia ferruginea</i>	Phyllanthaceae	Small tree	Nectar
<i>Cassia mimosoides</i>	Fabaceae	Herb	Nectar/Pollen
<i>Cassia sieberiana</i>	Fabaceae	Small tree	Pollen
<i>Centrosema pubescens</i>	Fabaceae	Herb	Nectar/Pollen
<i>Chromolaena odorata</i>	Asteraceae	Herb	Nectar/Pollen
<i>Cissus aralioides</i>	Vitaceae	Liana	Nectar
<i>Cissus arguta</i>	Vitaceae	Herb	Nectar
<i>Cissus populnea</i>	Vitaceae	Liana	Nectar/Pollen
<i>Combretum molle</i>	Combretaceae	Small tree	Nectar
<i>Combretum nigricans</i>	Combretaceae	Small tree	Nectar
<i>Commelina erecta</i>	Commelinaceae	Herb	Nectar/Pollen
<i>Corchorus olitorius</i>	Malvaceae	Herb	Nectar/Pollen
<i>Crossopteryx febrifuga</i>	Rubiaceae	Small tree	Nectar/Pollen
<i>Crotalaria retusa</i>	Fabaceae	Herb	Nectar/Pollen
<i>Croton hirtus</i>	Euphorbiaceae	Herb	Nectar/Pollen
<i>Ctenium elegans</i>	Poaceae	Herb	Pollen
<i>Daniellia oliveri</i>	Fabaceae	Tree	Nectar
<i>Desmodium gangeticum</i>	Fabaceae	Herb	Nectar
<i>Desmodium ramosissimum</i>	Fabaceae	Herb	Pollen
<i>Detarium senegalense</i>	Fabaceae	Tree	Nectar/Pollen
<i>Dichrostachys cinerea</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Entada africana</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Eulophia guineensis</i>	Orchidaceae	Herb	Pollen
<i>Euphorbia heterophylla</i>	Euphorbiaceae	Herb	Nectar
<i>Euphorbia hirta</i>	Euphorbiaceae	Herb	Nectar/Pollen
<i>Evolvulus alsinoides</i>	Convolvulaceae	Herb	Pollen

<i>Fadogia agrestis</i>	Rubiaceae	Herb	Nectar
<i>Fimbristylis dichotoma</i>	Cyperaceae	Herb	Pollen
<i>Flacourtia flavescens</i>	Salicaceae	Small tree	Pollen
<i>Gardenia erubescens</i>	Rubiaceae	Shrub	Nectar
<i>Gardenia ternifolia</i>	Rubiaceae	Shrub	Nectar
<i>Gmelina arborea</i>	Lamiaceae	Tree	Nectar
<i>Guiera senegalensis</i>	Combretaceae	Small tree	Nectar
<i>Holarrhena floribunda</i>	Apocynaceae	Tree	Nectar/Pollen
<i>Hymenocardia acida</i>	Phyllanthaceae	Small tree	Nectar/Pollen
<i>Hyparrhenia dissoluta</i>	Poaceae	Herb	Pollen
<i>Hyparrhenia smithiana</i>	Poaceae	Herb	Pollen
<i>Hyptis suaveolens</i>	Lamiaceae	Herb	Nectar/Pollen
<i>Isoberlinia doka</i>	Fabaceae	Small tree	Nectar
<i>Kyllinga erecta</i>	Cyperaceae	Herb	Nectar
<i>Lannea acida</i>	Anacardiaceae	Small tree	Nectar/Pollen
<i>Lannea microcarpa</i>	Anacardiaceae	Small tree	Nectar/Pollen
<i>Lannea velutina</i>	Anacardiaceae	Small tree	Nectar/Pollen
<i>Lonchocarpus sericeus</i>	Fabaceae	Small tree	Nectar
<i>Maytenus senegalensis</i>	Celastraceae	Small tree	Nectar
<i>Melothria maderaspatana</i>	Cucurbitaceae	Herb	Nectar
<i>Mimosa pudica</i>	Fabaceae	Herb	Pollen
<i>Mitracarpus scaber</i>	Rubiaceae	Herb	Nectar
<i>Mitragyna inermis</i>	Rubiaceae	Small tree	Nectar/Pollen
<i>Monechma depauperatum</i>	Acanthaceae	Herb	Nectar
<i>Ochna membranacea</i>	Ochnaceae	Small tree	Pollen
<i>Olax subscorpioidea</i>	Olacaceae	Small tree	Nectar
<i>Pachycarpus lineolatus</i>	Apocynaceae	Herb	Nectar/Pollen
<i>Pandiaka angustifolia</i>	Amaranthaceae	Herb	Nectar
<i>Panicum brevifolium</i>	Poaceae	Herb	Pollen
<i>Parinari curatellifolia</i>	Chrysobalanaceae	Small tree	Nectar
<i>Parkia biglobosa</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Paspalum scrobiculatum</i>	Poaceae	Herb	Pollen
<i>Passiflora foetida</i>	Passifloraceae	Herb	Nectar/Pollen
<i>Pennisetum polystachion</i>	Poaceae	Herb	Pollen
<i>Pericopsis laxiflora</i>	Fabaceae	Small tree	Nectar
<i>Piliostigma thonningii</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Pterocarpus erinaceus</i>	Fabaceae	Small tree	Nectar
<i>Saba senegalensis</i>	Apocynaceae	Liana	Nectar
<i>Sarcocephalus latifolius</i>	Rubiaceae	Liana	Nectar/Pollen
<i>Securinega virosa</i>	Phyllanthaceae	Shrub	Nectar
<i>Senna siamea</i>	Fabaceae	Tree	Pollen
<i>Sida acuta</i>	Malvaceae	Herb	Nectar/Pollen
<i>Sida cordifolia</i>	Malvaceae	Herb	Nectar
<i>Sida rhombifolia</i>	Malvaceae	Herb	Nectar/Pollen
<i>Sida urens</i>	Malvaceae	Herb	Nectar
<i>Spigelia anthelmia</i>	Loganiaceae	Herb	Nectar
<i>Sporobolus pyramidalis</i>	Poaceae	Herb	Pollen
<i>Sterculia setigera</i>	Malvaceae	Small tree	Nectar/Pollen
<i>Strychnos innocua</i>	Loganiaceae	Small tree	Nectar
<i>Strychnos spinosa</i>	Loganiaceae	Small tree	Nectar
<i>Synedrella nodiflora</i>	Asteraceae	Herb	Pollen
<i>Syzygium guineense</i>	Myrtaceae	Small tree	Nectar/Pollen
<i>Tamarindus indica</i>	Fabaceae	Small tree	Nectar/Pollen
<i>Terminalia avicennioides</i>	Combretaceae	Small tree	Nectar/Pollen
<i>Terminalia glaucescens</i>	Combretaceae	Small tree	Nectar/Pollen
<i>Terminalia laxiflora</i>	Combretaceae	Small tree	Nectar
<i>Triumfetta rhomboidea</i>	Malvaceae	Herb	Pollen
<i>Vernonia cinerea</i>	Asteraceae	Herb	Pollen
<i>Vernonia guineensis</i>	Asteraceae	Herb	Nectar
<i>Vitex doniana</i>	Lamiaceae	Small tree	Nectar/Pollen
<i>Vitellaria paradoxa</i>	Sapotaceae	Small tree	Nectar/Pollen
<i>Waltheria indica</i>	Malvaceae	Herb	Nectar/Pollen
<i>Ximenia americana</i>	Ximeniaceae	Small tree	Nectar/Pollen
<i>Zanthoxylum zanthoxyloides</i>	Rutaceae	Small tree	Nectar/Pollen

**Evolution of the specific species richness of flowering plants according to time**

The monthly variation in the number of flowering plant species during the observation period is shown in Fig. 3. The number of flowering herbaceous species ranged from 2 in February to 49 in September. Flowering of herbaceous species was most abundant between June (19 species) and October (37 species), peaking in September (49 species).



**Fig. 3.** Monthly variation in the number of flowering plant species

As for the number of flowering woody species, it ranged from 7 in July to 32 in March. Flowering of woody species was most abundant between January (24 species) and May (23 species), peaking in March (32 species).

The total number of flowering species ranged from 23 in December to 60 in September. The trend in the total number of flowering species throughout the months showed two peaks : the first was recorded in March with 40 species, and the second in September with 60 species.

**Evolution of the specific richness of honey plants according to time**

The monthly variation in the number of plant species visited by bees is shown in Fig. 4. The number of herbaceous honey plants recorded each month ranged from 1 in February to 37 in September. The number of herbaceous species foraged by bees was high between June (13 species) and October (26 species), peaking in September (37 species).

The minimum number of woody honey plant species recorded per month was 7, observed in July. The maximum number of woody honey plant species

recorded per month was 28 and was recorded in March. The number of woody species foraged by bees was highest between January (22 species) and May (19 species), peaking in March (28 species).

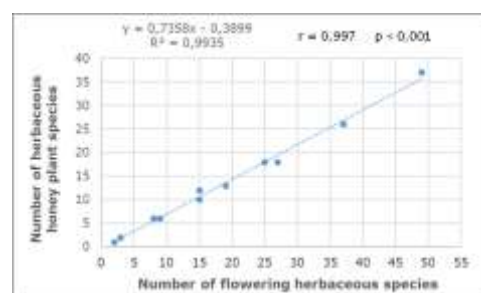


**Fig. 4.** Monthly variation in the number of honey plant species

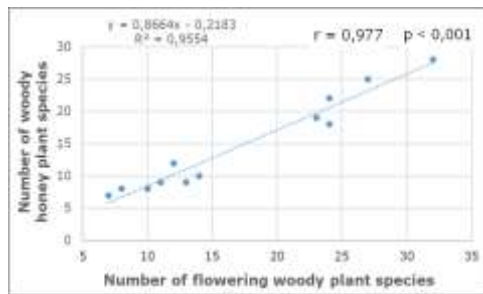
The total number of honey plant species recorded each month was lowest in December (16 species). The highest monthly species richness of honey plants was recorded in September (46 species). The trend in the total number of honey plant species throughout the months showed two peaks: the first was recorded in March with 34 species, and the second in September with 46 species.

**Relationship between monthly variation in the number of flowering species and monthly variation in honey plant species richness**

Simple linear regression analysis showed that there is a very strong and significant positive correlation ( $r = 0.997$  and  $p < 0.001$ ) between the number of flowering herbaceous species and the number of herbaceous honey plant species (Fig. 5). The monthly variation in the number of herbaceous honey plant species is explained by the monthly variation in the number of flowering herbaceous species to a degree of 99.35%.



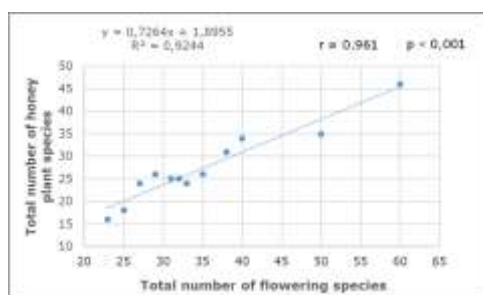
**Fig. 5.** Correlation between the number of flowering herbaceous plant species and the number of herbaceous honey plant species



**Fig. 6.** Correlation between the number of flowering woody plant species and the number of woody honey plant species

The correlation between the number of flowering woody species and the number of woody species visited by bees is shown in Fig. 6. The number of woody honey plant species is positively, very strongly, and significantly correlated with that of flowering woody species ( $r = 0.977$  and  $p < 0.001$ ). The proportion of the monthly variation in the number of woody honey plant species explained by the monthly variation in the number of woody flowering plant species is 95.54%.

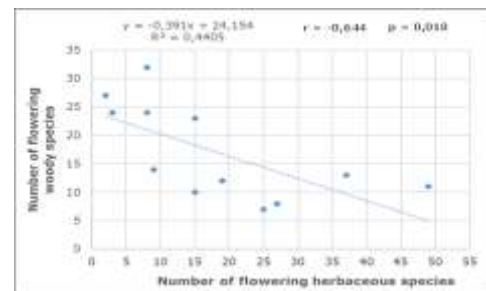
The correlation between the total number of flowering species and the total number of honey plant species (Fig. 7) is positive, very strong, and significant ( $r = 0.961$  and  $p < 0.001$ ). The proportion of the monthly variation in the total number of honey plant species explained by the monthly variation in the total number of flowering species is 92.44%.



**Fig. 7.** Correlation between the total number of flowering plant species and the total number of honey plant species

#### Relationship between monthly variation in the number of flowering herbaceous species and monthly variation in the number of flowering woody species

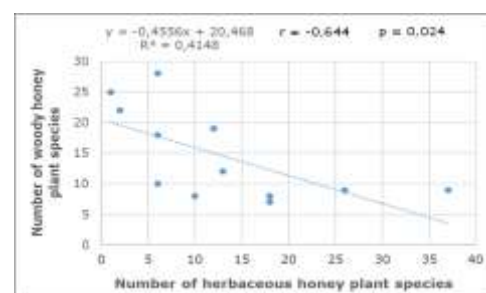
The correlation between the number of flowering herbaceous species and the number of flowering woody species (Fig. 8) is negative, strong, and significant ( $r = -0.644$  and  $p = 0.018$ ). The monthly variation in the number of flowering woody species explained by the monthly variation in the number of flowering herbaceous species represents a proportion of 44.05%.



**Fig. 8.** Correlation between the number of flowering herbaceous plant species and the number of flowering woody plant species

#### Relationship between monthly variation in the number of herbaceous honey plant species and monthly variation in the number of woody honey plant species

The correlation between the number of herbaceous honey plant species and the number of woody honey plant species (Fig. 9) is negative, strong, and significant ( $r = -0.644$  and  $p = 0.024$ ). The proportion of the monthly variation in the number of woody honey plant species explained by the monthly variation in the number of herbaceous honey plant species is 41.48%.



**Fig. 9.** Correlation between the number of herbaceous honey plant species and the number of woody honey plant species

#### DISCUSSION

Flowering was observed in 145 of the 243 plant species identified. Thus, the proportion of species that flowered

relative to the total flora of the site during the observation period was 59.67%. Yédomonhan (2009) reported flowering ratios of 71.29% and 69.45% in two areas of Benin after two years of observation. According to this author, these results are attributed, on the one hand, to the phenological profile of the species and, on the other hand, to the timing and duration of the floristic surveys. In fact, some tropical plant species have an annual flowering cycle lasting less than a week, while others have a sub-annual flowering cycle, meaning they flower less than once a year (Sabatier, 1985; Mure, 1986; Sabatier and Puig, 1986). Thus, it is possible that species with a flowering period of less than a week were not recorded during the monthly field visits. Similarly, it is possible that plants with a supra-annual flowering cycle never flowered during the year of data collection. This suggests that the results reported in this study may underestimate the number of species that flowered. The specific richness of honey plants recorded (112 species) corresponds to 77.24% of the total number of plant species observed to be in flower. This indicates that bees select specific plant species from their environment for their food. This selection ratio is higher than those reported by Yédomonhan *et al.* (2009) in Manigri in the Sudano-Guinean zone (32.7%), Coulibaly (2014) in Dimbokro in the Sudano-Guinean zone (39.63%), and Ahouandjinou *et al.* (2017) in the Kouandé Hills Protected Forest in the Sudano-Guinean zone (30.9%). This selection by foraging bees is believed to be influenced by several factors, such as the floral composition of the foraging area, the phenology of the species present, and their floral morphology (Lobreau-Callen and Damblon, 1994; Bakenga *et al.*, 2000). These results suggest that a site's beekeeping potential is not directly linked to the number of flowering species it contains. In fact, this potential depends more on the number, beekeeping value, and abundance of the honey plant species present, as well as the availability of floral resources through time (Yédomonhan *et al.*, 2012; Ahouandjinou *et al.*, 2017).

The correlation between the monthly species richness of flowering herbaceous plants and that of flowering woody plants is negative, strong, and significant ( $r = -0.644$  and  $p = 0.018$ ).

Indeed, flowering herbaceous species were abundant during the wet season, while the number of flowering woody species was low. Conversely, during the dry season, the species richness of flowering woody species was high, whereas that of flowering herbaceous species was low.

Thus, the variation in the species richness of flowering plants over time reflects a constant availability of floral resources throughout the year. The abundant flowering of woody species during the dry season and that of herbaceous species during the rainy season appears to be a general characteristic of dry tropical zones (Yédomonhan *et al.*, 2009; Ahouandjinou *et al.*, 2017).

The correlation between the number of herbaceous honey plant species and the number of woody honey plant species is negative, strong, and significant ( $r = -0.644$  and  $p = 0.024$ ).

Indeed, during the wet season, the number of herbaceous honey plant species was high, while the number of woody honey plant species was low. Conversely, during the dry season, the species richness of woody honey plants was high, whereas that of herbaceous honey plants was low. Thus, the temporal variation in the species richness of honey plants indicates a continuous availability of floral resources exploited by the honeybee for its diet throughout the annual cycle. This availability of floral resources includes two periods of abundance. The first period of abundance is characterized by an important flowering of woody honey plants during the dry season. The second period of abundance is marked by a predominant flowering of herbaceous honey plant species during the rainy season.

## CONCLUSION

The aim of this study was to determine the species richness of honey plants in the Badenou classified forest and the availability of their floral resources over time, with a view to developing modern beekeeping. The monitoring of honey plant foraging

by honeybees identified 112 honey plant species out of a total of 145 plant species that flowered. The species richness of flowering plants and that of honey plants varies through time. The floral resources exploited by honeybees for food are available year-round, with two periods of abundance. The first period of abundance, corresponding to the dry season, is characterized by the abundant flowering of woody honey plants. The second period of abundance, corresponding to the rainy season, is marked by the important flowering of herbaceous honey plant species. Thus, the species richness of honey plants in the Badenou classified forest and the availability of their floral resources over time have been determined. These characteristics are favorable to the development of modern beekeeping. However, the study of physicochemical and organoleptic characteristics of honeys produced should help identify any distinctive properties that could be used to enhance their commercial value.

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