Convergence of plants used by local populations and the diet of elephants in Azagny National Park (South-West, Côte d'Ivoire).

KPAN Blaise Wokapeu[1,*], KOMAN Romuald Silvère[2], KONAN Yao[4], WITABOUNA Kone Mamidou[3], DJAKALIA Ouattara[1].

[1] Laboratory of Natural Environments and Biodiversity Conservation, Botanical Research and Training Unit, Felix HOUPHOUËT-BOIGNY University, Abidjan, Côte d'Ivoire.
[2] Environmental Sciences Department, Training and Research Unit for Governance and Sustainable Development, Bondoukou University.
[3] Laboratory of Botany and Valorization of Plant Diversity, Natural Sciences Training and Research Unit, Nangui ABROGOUA University, Abidjan, Côte d'Ivoire.
[4] National Floristic Center (CNF), Abidjan, Côte d'Ivoire.

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Abstract:
This study aimed to synthesize the knowledge required to create a repertoire of medicinal plants used by local populations and consumed by elephants in the Azagny National Park (ANP). To this end, a survey was carried out among 87 people living in 5 localities surrounding the PNA. The majority were women (60 %), mainly housewives (35.6 %). Generally uneducated (48 %), the average age of those surveyed was between 55 and 65. Three species are the most widely used: *Aframomum melegueta* (36.74 %), *Ficus exasperata* (18.14 %) and *Anchomanes difformis* (10.23 %). The recipes administered, mostly multi-species (56 %), are used to fight cutaneous diseases (41 %) and diseases of the digestive tract (40%). Seeds (45 %) and leaves (34 %) are the most commonly used organs. Kneading (71 %) and decoction (22 %) are the most frequently used preparation methods. Treatments are mainly administered orally (32.14 %) and dermally (26.59 %), and are taken in the morning and evening (71 %) for up to 7 days (35.8 %). The plants are mainly collected in the field (51 %), where they are abundant (66 %). These results can be used as a database for further studies to develop an Improved Traditional Medicine (ITM).

Keywords: Medicinal plants, elephants, National Park.

Convergence entre les plantes utilisées par les populations locales et le régime alimentaire des éléphants dans le parc national d'Azagny (Sud-Ouest, Côte d'Ivoire)

Résumé :
La présente étude vise à faire la synthèse des connaissances permettant de mettre en place un répertoire de plantes médicinales utilisées par les populations riveraines et consommées par les éléphants du PNA. Pour ce faire, une enquête a été menée auprès de 87 personnes présentes dans 5 localités environnantes au PNA. Les femmes à 60 % et principalement des ménagères (35.6 %) sont majoritaires. Généralement sans instruction (48 %), la moyenne d'âge des enquêtés se situe entre 55 et 65 ans. Trois espèces sont les plus utilisées : *Aframomum melegueta* (36.74 %), *Ficus exasperata* (18.14 %) et *Anchomanes difformis* (10.23 %). Les recettes administrées, majoritairement plurispécifiques (56 %), permettent de lutter contre les maladies dermatologiques (41 %) et les maladies du tube digestif (40 %). Les graines (45 %) et les feuilles (34 %) constituent les organes les plus utilisés. Le pétrissage (71 %) et la décoction (22 %) sont les modes de préparation les plus fréquemment employés. Les traitements sont principalement administrés par voie orale (32.14 %) et cutanée (26.59 %) et sont pris le matin et le soir (71 %) sur une durée maximale de 7 jours (35.8 %). Les plantes sont principalement collectées au champ (51 %) où elles y sont en abondance (66 %). Ces résultats peuvent être utilisés comme une base de données pour des études approfondies afin de mettre au point un Médicament Traditionnel Amélioré (MTA).

Mots clés : Plantes médicinales, éléphants, Parc.

Introduction

In Africa, and particularly in Côte d'Ivoire, rural populations rely heavily on traditional medicine, which draws its remedies directly from the local flora. The latter, especially in tropical forests, offers a remarkable diversity of medicinal plants (Dibong et al., 2011; Tchatat et al., 1999). Azagny National Park (ANP), a tropical rainforest ecosystem, is a relevant example of this botanical richness.

The PNA is an area where local human populations coexist with wildlife, including elephants. Although rich, this ecosystem is under increasing pressure due to the exploitation of plant resources by both groups for their food and health needs (Adiko et al., 2020; Kouamé, 2009). Indeed, local populations and elephants share a varied diet consisting of grasses, leaves, roots, and fruits from various forest species, access to which varies with the seasons (Kouamé et al., 2017; Boukoulou et al., 2012). However, this interface between human and animal resource use remains poorly understood.

In this context, the "One Health" approach, which promotes an integrated vision of human health, animal health, and the state of ecosystems, offers a particularly relevant

(*) Correspondance : Kpan B.W. ; e-mail : kpan.blaise@ufhb.edu.ci ; tél. : (+225) 0778184098.

conceptual framework. It is on the basis of this approach that the present study was conducted, with the aim of exploring the close links between these three dimensions within the PNA. Although numerous studies have been conducted on the diet of elephants in Côte d'Ivoire (Soulemane, 2003) and specifically in the PNA (Kouamé et al., 2017), none seem to have focused on the intersection between this diet and the local traditional pharmacopoeia. This lack of knowledge about shared medicinal plants is an obstacle to the integrated and sustainable management of the park's resources.
To remedy this, the present study proposes to list the medicinal plants used by local populations and consumed by elephants in Azagny National Park, and to collect information on the availability of plants of therapeutic interest consumed by elephants in the park.

Material and methods

1. Material

1.1. Presentation of the study environment

Formerly a partial wildlife reserve in 1960, the ANP was created by decree no. 81-218 of April 2, 1981, following the decommissioning of a large part of the area under cultivation (Konan, 2008). Côte d'Ivoire's first RAMSAR site since 1996, it covers an area of 19,400 ha. Located in the south of Côte d'Ivoire between latitudes 5°9' and 5°17' North and longitudes 4°47' and 4°57' West (Gnagbo, 2015), most of it lies in the Sub-prefecture and Département of Grand-Lahou; only a portion of it in its eastern part lies in the Jacqueville's sub-prefecture of and in Abidjan's department (Gnagbo, 2015). Exclusively reserved for conservation, education and tourism, the park is bounded to the west by the Bandama River, to the southeast by the Ebrié Lagoon and to the south by the Azagny artificial canal dug in 1920 (Wango et al., 2013) and to the north by village plantations (Lauginie, 2007). Several localities surround it, including Nandibo I, Nandibo II, Djidjikro, Irobo, Gboyo, Toukouzou, Kraffi, Amessan N'guessandon, Djateket, Nmouzou, Braffedon and N'zida (Fig.1).
Located in the ombrophilous sector of the Guinean domain (Kouamé, 2009), the ANP's vegetation appears as a mosaic of plant formations that are very different from one another. They range from grassy savannah to dense forest (Bouichou, 1978), passing through secondary formations.
There are coastal savannahs, swamp formations, thickets, dense evergreen forests, secondary forests, swamp-dominated forests, coastal forests, mangrove forests and abandoned plantations. The great diversity of the park's biotopes has fostered the presence of many emblematic animal species. There are monkeys, turtles, buffalo, elephants, birds and crocodiles. The park's terrain is relatively flat, consisting of a vast marshy depression dominated to the north by a series of low plateaus (Kouamé, 2009). The climate in and around the park is sub-equatorial (Avenard et al., 1971). It comprises a rainy season and a dry season, each extending over two periods. The rainy season runs from March to July and from September to December, while the dry season extends from January to February and through August (Kouamé, 2009). Average rainfall is 1,650 mm. The average annual temperature is 26°C and the average relative humidity is around 85 % (Avenard et al., 1971). Human activities include farming, hunting, fishing and gathering. The Park's northern and western zones are the most affected by deforestation (Konan, 2008).

1.2. Plant studied

The choice of plants for our study was made taking into account the work of Kouamé et al. (2017). Thus, the survey focused on the ten plants most consumed by elephants in ANP. These were *Aframomum melegueta* (Zingiberaceae); *Aframomum sceptrum* (Zingiberaceae); *Albizia adianthifolia* (Fabaceae); *Anchomanes difformis* (Araceae); *Echinochloa pyramidalis* (Poaceae); *Ficus exasperata* (Moraceae); *Ficus mucuso* (Moraceae); *Hypselodelphys violacea* (Marantaceae); *Marantochloa congensis* (Marantaceae); *Sacoglottis gabonensis* (Humiriaceae).

2. Methods

2.1. Selection site

The study was conducted in villages bordering Azagny National Park (ANP) in Côte d'Ivoire. Of the 12 villages surrounding the park, a selection was made following an exploratory mission conducted from April 24 to May 6, 2023. A non-probabilistic sampling method, based on guided selection (or reasoned choice), was used to select the survey sites. This method was chosen to ensure that the villages were representative according to predefined criteria deemed relevant to the study's objectives.

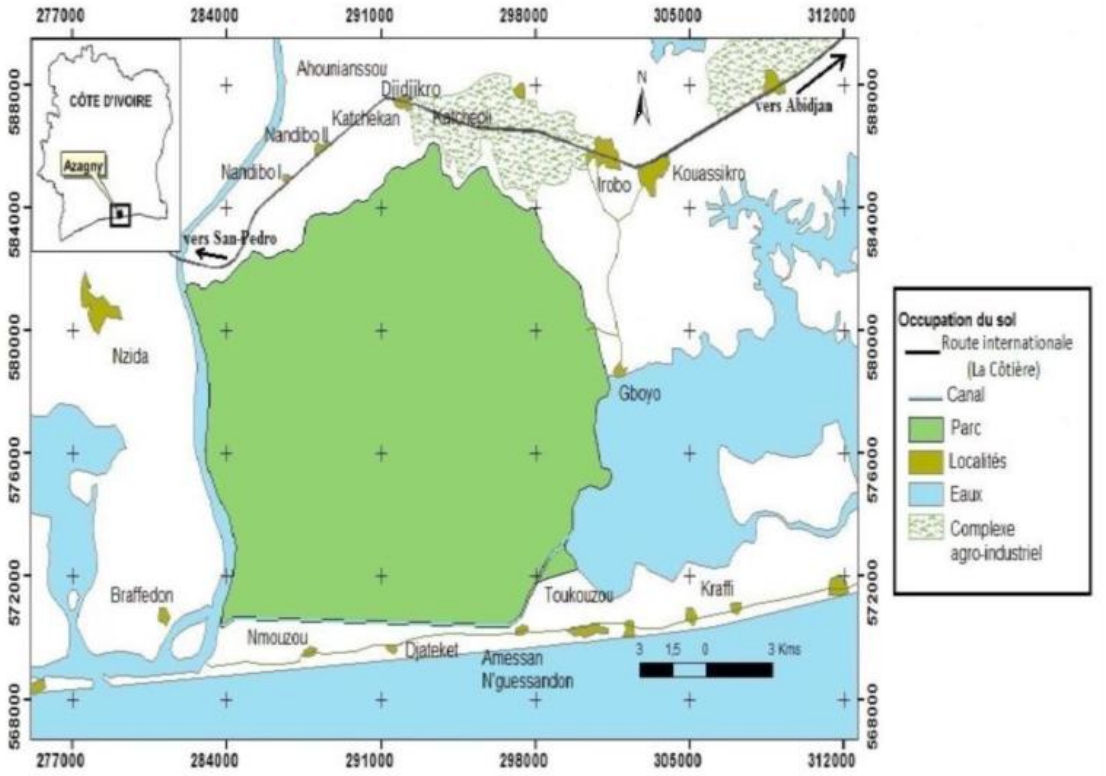

Fig 1: Azagny National Park location map (Gnagbo, 2015)

The selection criteria were as follows:

- ✓ Geographical proximity to the park;
- ✓ Accessibility of the village;
- ✓ Ethnic diversity of the populations;
- ✓ Known anthropogenic influence of the populations on the park;
- ✓ Population density.

Based on these criteria, five villages were selected for the survey phase: Nandibo I, Nandibo II, Djidjikro, Irobo, and Gboyo (Fig.2).

2.2. *Preliminary survey*

Before the surveys began, administrative and community procedures were undertaken. Research authorization was obtained from the Grand-Lahou town hall and the sector chief of the Ivorian Office of Parks and Reserves (OIPR). Subsequently, contact was established with the village authorities (village chiefs) and the presidents of the Village Conservation and Development Associations (AVCD) of the selected sites. These meetings provided an opportunity to present the objectives of the study, obtain the communities' agreement, and request their support, particularly in the form of assistance from a guide-interpreter with a good knowledge of the local flora.

2.3. *Data Collection*

Ethnobotanical data were collected using semi-structured interviews, a method that has been proven effective in similar studies (Koulibaly et al., 2016). A pre-designed questionnaire, inspired by previous methodologies (Zerbo et al., 2007; Tra Bi et al., 2008; Fah et al., 2013), served as a guide for the interviews. The information collected focused on the vernacular names of the plants, the parts used, the diseases treated, the methods of preparation and administration, and perceptions of elephant consumption of these plants.

A total of 87 people were interviewed. The distribution of respondents by village is as follows (Fig.2): 20 people in Nandibo I, 25 people in Nandibo II, 14 people in Djidjikro, 12 people in Irobo, and 16 people in Gboyo.

2.4. *Collection and Identification of Botanical Specimens*

A botanical sample collection campaign was carried out in June 2023 in the area around the village of Nandibo II, where six species mentioned during interviews were collected. The collection was carried out with the help of a local guide to ensure that the vernacular names corresponded to the specimens. The samples were then prepared for herbarium construction. Scientific identification of the species was carried out at the National Center for Floristics at Félix

Houphouët-Boigny University, by comparison with specimens from the National Herbarium of Côte d'Ivoire and in consultation with botanical experts.

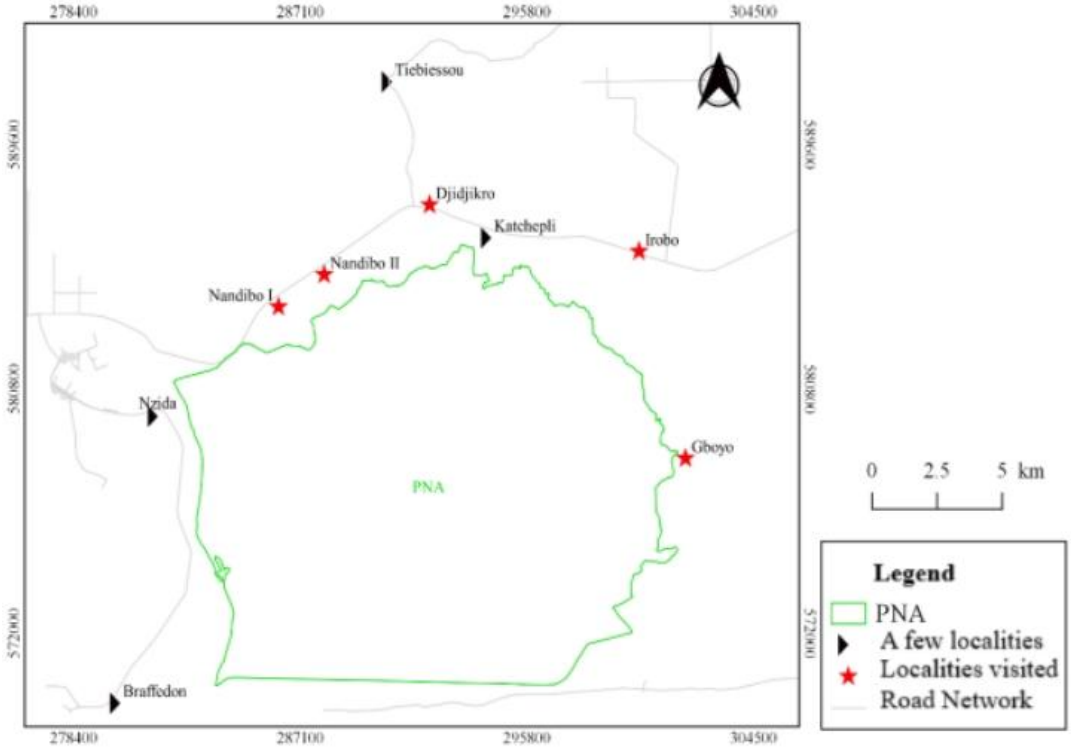

Fig 2: Location map of surveyed localities

3. Data processing

Data were entered using EpiData 3.1 software, then transferred to Excel 2016 software to obtain tables and figures; all this to better appreciate and explain the level of knowledge of surveyed plants, used by populations and entering the diet of ANP elephants. Once the survey sheets had been tabulated, the data was analyzed to determine the frequency of quotation (Fc), the confirmation index or informant consensus (ICs) and the frequency of occurrence (Fo) for each species, in order to better interpret the cultural and medicinal value of the plants studies.

Species Citation Frequency is used to assess the level of knowledge of the species studied. She expresses the intensity of use of each species without specifying the most commonly used species for each category of use. Taking into account the work of Sylla et al. (2018), it was determined for each species according to the following formula (1):

$$Fc = (NP/NT) \times 100 \quad (1)$$

Where,

NP = number of times the species is cited and *NT* = total number of citations.

However, this index does not take into account the respondents' level of knowledge for each category of use.

For the present study, we used the original formula proposed by Ilumbé et al. (2014). to express the confirmation index or informant consensus (ICs). Thus, informant agreement on the plants used is calculated as follows :

$$ICs = N_a / N_t \quad (2)$$

Where,

N_a = number of people who cited this species and N_t = total number of people interviewed.

The Confirmation Index or Informant Consensus varies between 0 and 1. A low value, close to 0, indicates that informants disagree about the plants used. A value close to 1 indicates a high or total consensus on plant use.

The original formula proposed by Dajoz (2000) was used to express the frequency of occurrence. Thus, the frequency of involvement of a plant in recipes is calculated as follows:

$$Fo = (Pe/Pi) \times 100 \quad (3)$$

Where,

Pi = number of recipes containing the species (i) and *Pe* = total number of recipes collected.

It is expressed as a percentage of the total number of recipes collected, without taking

species abundance into account. The frequency of occurrence can take the following values:

- ✓Fo between 85 % and 100 %, the species is "very frequent"
- ✓Fo between 60 % and 85 %, the species is "frequent"
- ✓Fo between 50 % and 60 %, the species is "constant"
- ✓Fo between 25 % and 50 %, the species is 'incidental'
- ✓Fo less than 25 %, the species is "accidental".

A part from the data processing the technical equipment was used. The technical equipment consists of:

- Survey form (see appendices);
- Physical photo album of the plant species studied (see appendices);
- Pruning shears (for collecting samples);
- Newspaper, presses, and ties to keep the samples in good condition;
- Digital camera (for taking photographs) .

4. *Results and discussion*

4.1. Ethnobotanical study

The ethnobotanical survey involved interviews with 87 people in the localities studied. Most respondents were women (60 %). Nineteen ethnic groups were interviewed, the most important being the Agni (30 %), followed by the Sénoufo (21 %) and the Baoulé (14 %). Knowledge and use of the plants studied were widespread across all age groups. Knowledge and use were highest in the 55-65 age group (28.7 %), followed by the 45-55 age group (26.4 %) and the 35-45 age group (23 %). The respondents came from a variety of professions. Housewives topped the list at 35.6 %, followed by planters at 32.2 % and shopkeepers at 13.8 %. With regard to level of education, the results show that 48 % of people had no education at all (Table I).

Table I: Socio-demographic characteristics of respondents in the localities visited (n=87).

Parameters	**Effective**	**Percentage**
Sex		
Male	35	40
Female	52	60
Ethnicity		
Agni	26	30
Senoufo	18	21
Baoule	12	14
Malinke	6	7
Mossi	6	7
Bambara	3	3
Bete	2	2
Dioula	2	2
Yacouba	2	2
Abbey	1	1
Ahizi	1	1
Akye	1	1
Bobo	1	1
Dida	1	1
Djimini	1	1
Fon	1	1
Koyaka	1	1
Peulh	1	1
Yoruba	1	1
Age group		
[19-35]	10	11,5
[35-45]	20	23
[45-55]	23	26,4
[55-65]	25	28,7
]65;+[	8	9,2

<19]	1	1
Profession		
Housewife	31	35,6
Planter	28	32,2
Shopkeeper	12	13,8
Traditional practitioner	3	3,4
Dressmaker	2	2,3
Naturotherapist	2	2,3
Matron	2	2,3
Restore	1	1,1
Naturalist	1	1,1
Carpenter	1	1,1
Mechanic	1	1,1
Mason	1	1,1
Hairdresser	1	1,1
Craftswoman	1	1,1
Level of education		
Not educated	42	48
Primary	30	35
Secondary	12	14
Higher	3	3

4.2. Diversity of knowledge and categorization of uses of plant organs

Analysis of the information gathered shows that, on the 10 plants studied, only three are the most widely used by local people for their care: *Aframomum melegueta* (36.74%), *Ficus exasperata* (18.14 %) and *Anchomanes difformis* (10.23 %).

Various diseases were recorded. Cutaneous diseases (41%) and digestive tract diseases (40 %) were the most frequently treated.

Seeds, with a frequency of 45%, are the organ most frequently used in the recipes cited by respondents (Fig. 3).

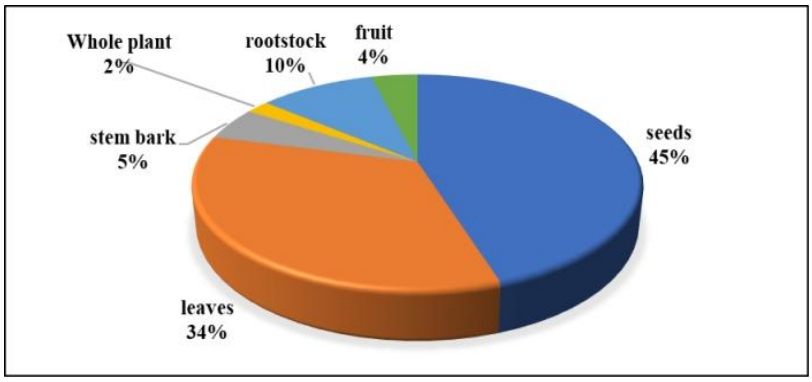

Fig 3 : Frequency spectrum according to parts used

They are followed by leaf-based recipes (34 %) and rhizome-based recipes (10 %). Preparation methods vary according to the treatments involved. The main preparation methods are kneading (71 %) and decoction (22 %) (Fig. 4).

With regard to the routes of administration of medicinal recipes, investigations revealed that the oral route was the most popular (32.14 %), followed by the cutaneous route (26.59 %) and the anal route (23.41 %) (Fig. 5).

4.3. Parameters processed

- *Species citation frequency (Fc)*

The species most cited by the populations are, in descending order of citation frequency, *Aframomum melegueta* (Fc = 37 %), *Ficus exasperata* (Fc = 18 %) and *Anchomanes difformis* (Fc = 10 %) (Table II).

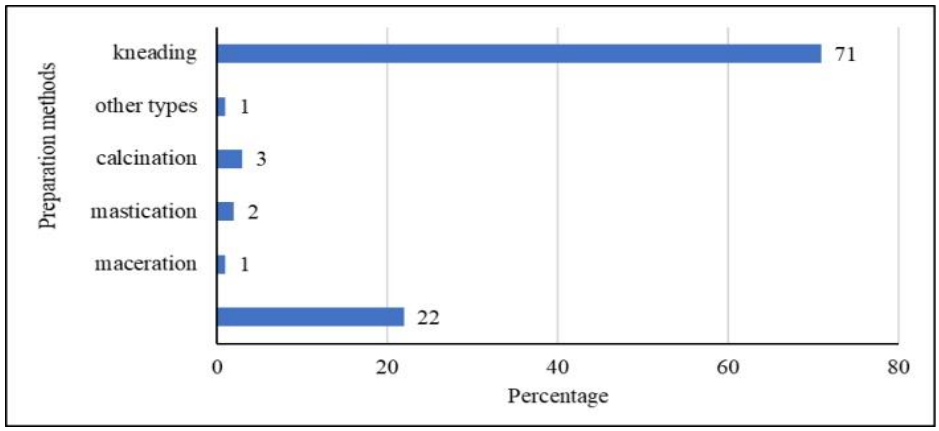

Fig 4 : Frequency spectrum by preparation method

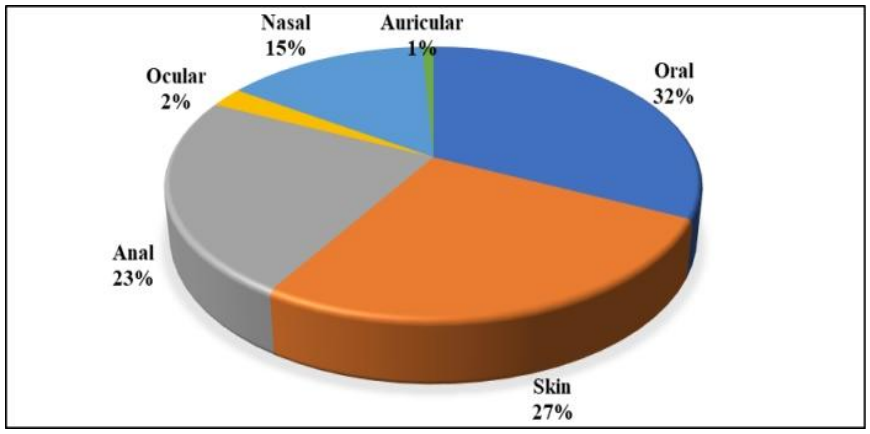

Fig 5 : Histogram of frequencies by route of administration

- *Consensus Index (CIs)*

The Consensus Index is close to 1 for just one species, *Aframomum melegueta* (CIs = 0.87) (Table II); the others have CIs below 0.5.

- *Frequency of occurrence (Fo)*

Analysis of frequencies of occurrence shows that only one species is "very frequent", *Aframomum melegueta* (with Fo = 92 %) (Table II). We also note the presence of "accessory" species such as Ficus exasperata and *Anchomanes difformis*, as well as "accidental" species such as *Aframomum sceptrum, Ficus mucuso, Albizia adianthifolia, Echinochloa pyramidalis, Hypselodelphys violacea* and *Sacoglottis gabonensis*.

Table II: Presentation of species according to parameters studied

Scientific names	Families	Number of informants	Number of citations	FC (%)	FO	ICs
Aframomum melegueta K. Schum.	Zingiberaceae	76	80	37	92	0,87
Ficus exasperata Vahl	Moraceae	37	38	18	44	0,43
Anchomanes difformis (Bl.) Engl.	Araceae	21	22	10	25	0,24
Aframomum sceptrum (Oliv. & D. Hanb.) K. Schum.	Zingiberaceae	19	18	9	21	0,22
Ficus mucuso Welw. ex Ficalho	Moraceae	18	19	9	22	0,21
Albizia adianthifolia (Schum.) W. F. Wight	Fabaceae	16	16	8	18	0,18
Echinochloa pyramidalis (Lam.) Hitchc. & Chase	Poaceae	8	10	4	11	0,09
Hypselodelphys violacea (Ridl.) Milne-Redh.	Marantaceae	6	6	3	7	0,07
Sacoglottis gabonensis (Baill.) Urb.	Humiriaceae	5	5	2	6	0,06

Legend: ***Fc****: Frequency of species citation,* ***ICs:*** *Species confirmation index,* ***Fo****: Frequency of occurrence*

5. *Discussion*

This study, which aimed to establish a list of medicinal plants shared between local communities and elephants in Azagny National Park, highlighted several key aspects concerning local ethnobotanical knowledge and its implications. Aframomum melegueta is the most frequently cited species, but also the one with the strongest consensus regarding its use. This strong agreement, which contrasts with the low consensus observed for other plants, suggests that its use is widely shared and validated within the community. This intensive use is also supported by previous work by Osuntokun (2020) and Doherty et *al.* (2010). These authors confirm the species' richness in secondary metabolites (tannins, flavonoids, alkaloids), thus validating its perceived effectiveness in treating the most common ailments identified, namely skin and digestive diseases (Diatta et *al.,* 2013; Saraka et al., 2018). The latter reflect the general health profile of the region, indicating that the local pharmacopoeia is directly adapted to the primary health needs of the populations. (Okwu, 2004; PNLP, 2005; Sylla et *al.* 2018). However, they contradict the results obtained by Raoufou et al. (2013) and El Hafian et *al.* (2014), with 49 % and 34.6 % of diseases affecting the digestive tract, respectively.

Furthermore, our study highlights therapeutic and collection strategies that have direct implications for conservation. The predominant use of seeds over vital organs such as roots or bark is an ecologically less destructive practice, promoting more sustainable exploitation of plant resources (Ghasemi et *al.,* 2013; Idm'hand et al., 2019; Ali, 2019). Even more notably, the majority of medicinal plants are collected from fields and plantations rather than from the primary forest. This finding suggests that farmers play an active and potentially intentional role in the conservation of these species, preserving them within their crops for the services they provide. This practice is similar to a form of in situ conservation, which could be an important lever for sustainable management strategies for the park and its surrounding areas.

Kneading, the most common method of preparation, is a quick and simple technique. This could be explained by the fact that kneaded dough is quick to make and easy to preserve by drying. The most common method of preparation in the recipes is similar to that obtained by Orsot et *al.* (2015) and Yapi et *al.* (2016), whose work respectively showed the preeminence of kneading (30.4 3% and 38.60 %). The oral route, which is almost exclusively used, is not only simple to use but is also perceived as the least dangerous for remedies in raw form, as the active ingredients are mainly absorbed in the intestine (Sylla et *al.,* 2018). This result confirms the work of Ivorian authors such as Wangny et *al.* (2019) with 93 %, Yapi et *al.* (2016) with 35.94 %; Beninese: Ali (2019) with 82 %; Cameroonian: Dibong et *al.* (2011) with 94.44%; and Moroccan: El Hafian et *al.* (2014) with 77%. The frequent use of multi-species recipes suggests a strategy aimed at treating a wider range of symptoms or creating synergies between chemical compounds, although some authors highlight the risks associated with poorly controlled plant combinations (Sylla et *al.,* 2018).

Finally, the sociodemographic profile of respondents reveals that this knowledge is predominantly held by women (60 %) and older people (aged 55 to 65, 28.7 %), which is consistent with their central role in family care and the experience they have accumulated over the years. On the one hand, this data is identical to that of various authors who have conducted ethnobotanical studies in Côte d'Ivoire and Morocco. In Côte d'Ivoire, these include Béné et *al.* (2016) with 66.67 % women; El-Hafian et al. (2014) with 57.4 %; and El-Hilah et al. (2016) with 64.63 % women in Morocco. In addition, the majority of them were housewives (35.6 %). These two results can be explained by the fact that, as mothers, they are the ones who provide primary care, particularly to their children, and therefore have mastered the use of many plants. Conversely, there is a predominance of men interviewed in the studies by Saraka et al. (2018) at 60 % and Wangny et *al.* (2019) at 56.19 % conducted in Côte d'Ivoire. On the other hand, this result roughly confirms that of Guinnin et al. (2015), with 51.24 % for respondents aged between 40 and 65. According to Mehdioui and Kahouadji (2007), knowledge of the uses and properties of medicinal plants is generally acquired through long experience and passed down from one generation to the next, although this is not always guaranteed. The low level of formal education (48 % of respondents) also highlights the crucial role of oral tradition in transmitting this heritage. While this demonstrates the resilience of this knowledge system, it also exposes its great vulnerability, as any break in the chain of transmission could lead to an irreversible loss of valuable knowledge. These results corroborate those of El-Hilah (2016) and Kouamé et *al.* (2023), who estimated that 78.66 % and 48.5 % of respondents, respectively, had no education. However, they differ from

those of Honoré et al. (2016), in which more than half of the respondents had a primary school education.

Conclusion

This study has enabled us to compile a directory of medicinal plants used by local populations and consumed by elephants in the ANP. Eighty-seven (87) people were interviewed in 5 localities adjacent to the ANP using semi-structured interviews. Microphanerophytes (56 %) and species from the Guinéo-Congolese region (78 %) are respectively the most represented biological types and chorological affinities. *Aframomum melegueta* is the species most frequently used (36.74 %) in the composition of recipes, mainly multi-species (56 %). Skin (34%) and digestive tract (29 %) diseases are the most commonly treated. Seeds (45 %), kneading (71 %) and the oral route (32.14 %) are respectively the most commonly used plant organs, preparation method and administration route. Most of the species studied are harvested in the fields (51%) and are abundant there (66 %).

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