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Research article

Ethnobotanical study and vulnerability of medicinal plants used against the symptoms of COVID-19 in the Lomié subdivision, East Region of Cameroon

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ABSTRACT

Science has advanced to the point that traditional medicine is now a useful instrument for treating a wide range of human ailments. Indigenous peoples and local communities (IPLCs) do not, however, have access to the contemporary healthcare system. As a result, they turn to biological resources, which are the only readily available and accessible means of treating diseases like COVID-19 and flu outbreaks. In response to worldwide illnesses, this study aligns with the perspectives of traditional knowledge of biological resources, particularly therapeutic plants. Therefore, this study was aimed to document the use of the potential of medicinal plants by IPLCs in the Lomié subdivision to manage COVID-19 symptoms. In four villages in the Lomié subdivision Ekom, Payo, Eschiambor, and Kongo, ethnobotanical surveys, including semi-structured interviews on traditional usage of plants against Covid-19 symptoms, were carried out with 80 participants in order to meet all of the study specific objectives. For every species, a vulnerability index was established in order to evaluate the species fragility. To analyze the data, both descriptive and inferential statistics were applied. The findings show that the respondents are well aware of the symptoms of the COVID-19 and that gave them the ability to provide timely and efficient responses. The survey identified 43 species from 39 genera grouped in 28 families were used to treat COVID-19 symptoms, with bark being the most commonly used plant part (43.8%). Decoction was the most frequently used method of preparation (50%), and oral administration was the main route of administration (56.3%). Most of the plant species were harvested from secondary forests (44.2%), of which trees formed 48.8%. A total of 30 species were recorded to be

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vulnerable, with *Entandrophragma cylindricum* (Sprague) Sprague, *Milicia excelsa* (Welw.) Benth, *Myrianthus arboreus* P. Beauv., and *Trichoscypha aborea* (A. Chev.) A. Chev being the most vulnerable, with vulnerability index of 2.4. The results showed a strong non-causal relationship between vulnerability and the continuous and discontinuous explanatory parameters. The susceptibility of medicinal plants used to treat COVID-19 symptoms and the explanatory parameters had a statistically significant causal association, according to the binomial logistic regression model. In light of novel diseases like COVID-19, this study finds that traditional knowledge of medicinal plants is still widely held, especially among the indigenous and local population. It can also be very beneficial in the development of new medications for a variety of illnesses.

1. Introduction

COVID-19, a viral zoonosis, is a highly contagious respiratory disease caused by the latest coronavirus, proving fatal for individuals compromised by age or chronic illnesses. While 80% of cases remain mild, individuals over 60 or with cardiovascular, respiratory, or diabetic conditions face a higher risk, manifesting severe symptoms. Originating in Wuhan, China, in late 2019, COVID-19 escalated into a global pandemic, affecting over 215 countries and posing a significant public health emergency [1,2]. The transmission of COVID-19 from an infected person to a healthy person occurs mostly through respiratory agents expelled from the nose or mouth of the carrier. It can also be spread when a diseased person sneezes or coughs. Physical contact, such as shaking hands, touching surfaces and objects contaminated with germs, and touching the eyes, nose, and mouth without washing the hands, promotes contamination. As a result, hands touch many surfaces and can come into contact with the virus. Once contaminated, hands can transmit the virus to the eyes, nose, or mouth [3]. The most common symptoms of COVID-19 documented are cold, cough, fever, fatigue, and breathing problems [4–6]. In 2022, more than 479 million cases of infection have been recorded worldwide, with more than 6 million deaths. Africa is acknowledged to be the continent least affected by the COVID-19 pandemic, with 11 million cases and 250,000 deaths; more than 119,544 confirmed cases and 1927 deaths recorded in Cameroun [7].

The relative resilience of the African continent to the COVID-19 epidemic is a multifaceted phenomenon that has sparked considerable interest and debate among global health experts. Despite facing challenges such as limited access to conventional safety measures, including preventive vaccines and curative treatments, many African nations have demonstrated a notable ability to mitigate the impact of the virus. The reasons behind this resilience are complex and may involve factors such as demographics, existing immunity from prior exposure to related viruses, and effective public health strategies.

It is crucial to recognize that the disparity in vaccine accessibility across the continent plays a pivotal role in shaping the African response to the pandemic. While acknowledging that no vaccine offers absolute protection against emerging strains of SARS-CoV-2, the availability and distribution of vaccines can significantly reduce the severity of illness. Efforts to enhance vaccine equity and strengthen healthcare infrastructure are imperative to ensure a more comprehensive and equitable defense against the evolving challenges posed by the ongoing global health crisis [8]. Nevertheless, less developed tropical countries don't have adequately equipped health structures and many rural and urban populations in Africa often resort to using plants as an alternative form of healthcare [9]. It is well acknowledged for some decades that over 80% of the rural population uses them to secure their healthcare [10]. The role of African ethnomedicine may have been very instrumental in developing several plant-based medicines that address COVID-19 symptoms, including Apivirine, Fagaricin, Covid Elixir, and Covid Adsak [11], which may explain Africa's resilience to COVID-19.

The Congo Basin forests and their diverse ecosystems that cover approximately 200 million hectares of the world's ecosystems [12], are rich in natural resources that provide many opportunities for people's livelihoods [13]. In Cameroon, these forests, which cover nearly 46% of the country's territory and are home to nearly 8000 plant species from 220 families, 1800 genera, of which 815 species are endangered [14]. The rich biodiversity within these ecosystems plays a crucial role in sustaining the livelihoods of Indigenous Peoples and Local Communities (IPLCs). For these communities, their way of life intricately intertwines with the diverse array of forest products, forming the backbone of socio-economic activities such as fishing, hunting, traditional medicine, gathering, and agriculture. The profound connection to ancestral territories is reflected not only in their daily practices but also in the preservation of unique cultures, linguistic specificities, and the careful management of forest resources. Particularly noteworthy are the medicinal plants found within these ecosystems, which have demonstrated their indispensability in treating various diseases, including the formidable challenge posed by COVID-19. In response to the global pandemic, numerous studies have delved into the traditional knowledge of IPLCs, focusing on medicinal plants known for their efficacy in alleviating COVID-19 symptoms. These investigations highlight the invaluable role that indigenous wisdom and biodiversity play in contributing to the broader understanding of potential treatments. By recognizing and respecting the intricate relationship between IPLCs and their biodiversity environments, we not only safeguard unique cultural heritages but also tap into reservoirs of knowledge that can inform sustainable and effective approaches to public health challenges [4,8,15–17]. However, these studies were limited to the inventory of plants used to treat COVID-19 symptoms and do not inform on the knowledge of the symptoms, the parts of the plants used and the vulnerability of these species in the context of over-exploitation. This study is in line with the perspectives of valorisation of traditional knowledge of biological resources and in particular of medicinal plants in response to global diseases. This research focused on addressing four key points. Firstly, it delved into understanding the socio-profile of the respondents. Secondly, it explored the respondents' awareness of COVID-19 symptoms. Thirdly, it investigated the usage of medicinal plants in the Lomié district for combating COVID-19 symptoms, providing an ethnobotanical profile. Lastly, the study assessed the vulnerability of these plant species under pressure context. The overarching aim was to scrutinize the utilization of medicinal plants by indigenous people and local communities in managing COVID-19 symptoms in the Lomié subdivision. This involved characterizing socio-economic profiles, gauging awareness of COVID-19 symptoms, detailing ethnobotanical information on plant usage, and evaluating the vulnerability of species.

2. Materials and methods

2.1. Study area

The study was carried out in the Lomié subdivision, located in the Haut-Nyong division of the East Cameroon Region. It is situated at 3°0 5″ and 39°0 0 North latitude and 3°0 1″ and 15°0 0 East longitude and has an area of 13,000 km^2 (Fig. 1). The climate is equatorial and of the Guinean type, with two rainy seasons alternating with two dry seasons. The average temperature is around 24 °C, with the average minimum and maximum temperatures being 22.5 °C in July and 32.6 °C in April, respectively [18]. Lomié subdivision is situated in a forested area that includes plains and mountains. The relief is relatively flat, with average altitudes ranging between 600 and 700 m [19]. The research locale is characterized by prevalent ferralitic soils, hydromorphic soils in low-lying regions, and notably impoverished sandy or sandy-clay soils. Lomié falls within the Cameroon-Congolese phytogeographic domain, featuring a dense medium-altitude evergreen forest known as the Congolese forest, interspersed with semi-deciduous forest patches. Noteworthy botanical families in 2009 included Meliaceae and Sterculiaceae [18]. Lomié's population, estimated at 19,000, encompasses sedentary Bantou communities (Zime Kako, Ndjeme) and indigenous Baka, along with commercial migrant groups like the Bamoun and Haoussa. Agricultural pursuits, encompassing both sustenance and cash crops, constitute the primary socio-economic engagement for the Bantou, complemented by hunting, fishing, and non-timber forest products (NTFP) collection. Additional activities involve livestock husbandry, agricultural products harvesting and processing, as well as handicrafts. However, the region also contends with timber exploitation facilitated by logging enterprises, council initiatives, and community forests [19].

Selected field equipments were used for data collection and for the preservation of medicinal plant samples for further identification in the National Herbarium. Survey forms were used to collect information from respondents. A GPS for taking geographical coordinates. A notepad and pencils were also used for taking notes. Shears were used to collect plant samples during the field surveys. A digital camera was used to take pictures. A machete was used to clear the way and collect plant organs.

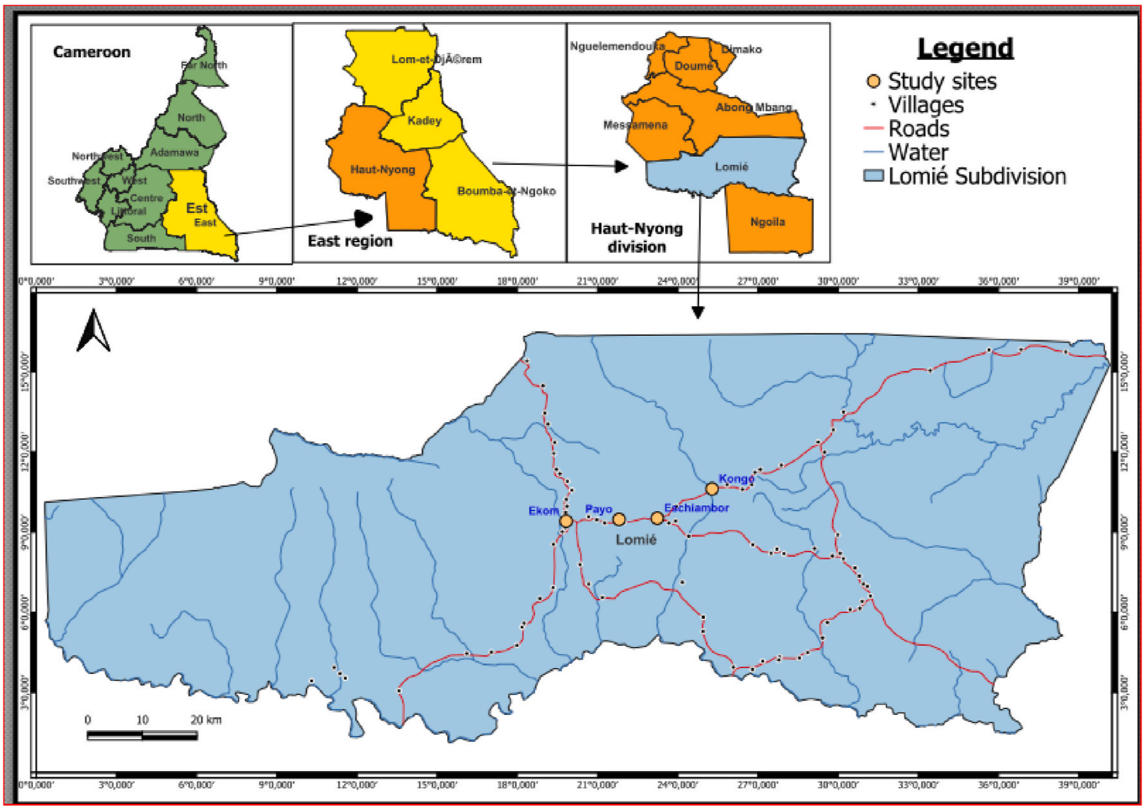

Fig. 1. Map of the study area.

2.2. Sampling design

Literature review was conducted to collect secondary data prior to primary data collection. The information obtained was utilized to identify data gaps and define sampling and parameters to be informed during data collection. The consent of the respondents was obtained after the information regarding the research work was presented to them. The information notice about the study was read and understood by the participants. They were given the freedom to participate in the study under the specified conditions.

The villages selected for the study, namely Ekon, Payo, Eschiambor, and Kongo, were based on specific criteria such as their distance from health infrastructure, population lifestyle, proximity to forests, and limited financial means to cover long distances from villages. The selection of villages involved proportional and weighted sampling, which was allocated according to the number of households. The study targeted both adult men and women, including indigenous peoples who had stayed in the locality during the COVID-19 pandemic. Proportional and weighted sampling, allocated according to the number of households was carried out [20]. A total of 80 people were interviewed: 23, 10, 12 and 25 people for the villages of Ekom, Payo, Eschiambor and Kongo respectively; and 5, 3 and 2 traditional healers for the villages of Kongo, Eschiambor and Payo respectively.

2.3. Data collection

Ethnobotanical surveys using semi-structured interviews were conducted from July to August 2021 in four villages in the Lomié subdivision: Ekom, Payo, Eschiammbor and Kongo. The tools for data collection were developed using the forms proposed by the "PHARMEL" African medicinal plant ethnobotanical data bank [21]. The data were collected through semi-structured open-ended interviews using local languages (Zime, Baka, and Kako) and French. The interview guide included questions on the respondent's profile (age, sex, education level, ethnic group and gender); the knowledge of COVID-19 symptoms treated; local names of medicinal plants used; plant parts used; recipes; modes of preparation of treatment; dosage, and side effects if any. Direct observations and casual conversations were also used to collect ethnomedicinal information.

2.4. Plant identification

Following the completion of interviews, field trips were appropriately conducted with the assistance of consenting individuals among the respondents, particularly traditional healers, to gather and identify specimens of medicinal plants utilized in treating symptoms of COVID-19. The techniques described by Schnell [22] were employed to collect the plants. The confirmation of local plant names cited in Zimé, Baka, Kako, or other local languages was carried out using the compendium of plant names in the ethnic languages of Cameroon by Onana & Mezili [23]. Sixty plant samples collected were conditioned, preserved, and deposited to the National Herbarium of Cameroon for confirmation of their systematic profile.

2.5. Vulnerability of plant species

The vulnerability of plant species was determined to find out the ecological impact of their use in treating the symptoms of COVID-19. According to Okafor & Ham [24], the most vulnerable species are those that are highly popular, grow slowly, reproduce with difficulty, inhabit fragile environments, and have a limited geographical distribution. To assess the vulnerability of plant species, the current study used many parameters such as: the popularity of the species, the plant organ used, the morphological type, the frequency of the plant in the environment [25], and the mode of collection [26]. A 3-km trail was delineated, and within each village, 30 sub-plots of 10 m each were framed, spaced 100 m apart, and arranged alternately from left to right, with the aim of assessing the abundance of herbaceous plants and shrubs possessing a diameter of less than 10 cm at breast height (DBH) [25]. In each sub-plot, all stems were enumerated and measured. The sub-plots were arranged in the same configuration as that employed for the inventory of trees and shrubs with a minimum DBH of 10 cm [25,27].

2.6. Data analysis

The coding and entry of data into the Excel 2013 spreadsheet for subsequent analysis were executed. The analysis of socio-economic data was performed utilizing SPSS Version. 20.0 to derive descriptive statistics. The description of the sixty sampled plant species was conducted by referencing various volumes of the Cameroon Flora housed at the National Herbarium and pertinent scientific literature, with emphasis on biological, morphological, and phytogeographical features. To evaluate the phytotherapeutic significance of the identified medicinal species, diverse parameters were calculated.

- **Frequency of citation (FC)**

The frequency of citation is calculated by dividing the number of times a species used for treating a specific disease is mentioned by a respondent, by the total number of respondents. This calculation helps to determine which species are most commonly used in the population [28]. The formula for frequency of citation is:

$$FC = \frac{\text{Number of citations of a species}}{\text{Total number of respondents}} * 100 \quad (1)$$

- **Fidelity index**

The fidelity index (FI) corresponds to the percentage of citation of a species in relation to the treatment of a particular disease. It is used to quantify the importance of a plant species in treating a particular disease or to assess the popularity of certain species used in the local area. It was calculated for the species most valued by the target population with a citation frequency of 10–60% using the following formula [29]:

$$FL = \frac{Ip}{lu} * 100 \tag{2}$$

Ip: being the number of respondents who suggest the use of the plant for the treatment of a particular disease; lu: the total number of respondents who mentioned this plant species for any other use.

- **Frequency of recipes (Fr) and frequency of recipe citations (Frc)**

Recipe frequency (Fr) and recipe citation frequency (Frc) were used to identify credible recipes for each disease [30]. Recipes with high Fr and Frc are considered credible. The Fr was calculated using the formula:

$$Fr = \frac{Ncr}{N} * 100 \tag{3}$$

with Ncr, the number of citations of a recipe treats a symptom of COVID-19; N, the total number of citations of all recipes treating the symptom of COVID-19.

$$Fcr = \frac{Ncr}{Nt} * 100 \tag{4}$$

with Ncr the number of citations of recipes for a given COVID-19 symptom and; N, the total number of citations of all recipes treating all COVID-19 symptoms.

- **Frequency of involvement**

The frequency of involvement (Cpr) is the contribution of each plant in the constitution of the recipe [30]. It is obtained using the formula:

$$Cpr = \frac{Nr}{Nt} * 100 \tag{5}$$

The scale for assessing the vulnerability of each species is as follows: 1, species not vulnerable for the considered parameter; 2, species with medium vulnerability; and 3, species with high vulnerability (Table 1).

Where Nr is the number of recipes that require the plant and Nt is the total number of recipes.

The vulnerability index (Iv) of each species was determined by calculating the average of the different values for each species, taking into consideration the combined effect of all parameters. The vulnerability of each species was categorized into three classes: not vulnerable, vulnerable, and highly vulnerable (Table 2).

Bivariate, multivariate, and inferential analyses were performed, and the vulnerability indices were computed. The primary

Table 1
Importance of the parameters involved in vulnerability assessment [25,26,30].

Parameters	Vulnerability to uncontrolled exploitation		
	Low (scale = 1)	Medium (scale = 2)	High (scale = 3)
Popularity	Low: Cpr <20	Medium 20 ≤ Cpr <60	High Cpr ≥60
Frequency in the environment	High FrRel ≥2/3 Frmax	Medium 1/3 Fmax ≤ FrRel < Frmax	Low FrRel <1/3 Frmax
Biotope	Ruderal, garden, food field, fallow	Secondary forest	Little disturbed or primary forest
Dissemination of diaspores	Autochory (ballochory, barochory)	Anemochory (pterochory, pogochory, sclerochory, plelochory)	Sarcochory, desmochory
Morphological type	Annual herb	Perennial herb, sub-shrub	Tree, shrub, liana
Plant organ	Leaf, latex, resin or serve	Fruit, seed	Stem or root bark, bulb, tuber, wood, whole plant
Mode of collection	Collecting		Picking, cutting
Stage of development	Old or senescent	Adult	Young
Pharmaceutical form	Ash, powder, ointment dried organ		Macerated, decocted, fresh organ

FrRel: relative frequency of the species in the surveys; Frmax: maximum frequency of the species.

Table 2
Vulnerability classes [25,26,30].

Vulnerability index	Class
Iv < 2	Not vulnerable
2 ≤ Iv < 2.5	Vulnerable
Iv ≥ 2.5	Highly vulnerable

inferential statistics employed include Pearson's Chi-square test, Cramer's Phi and V test, and bivariate logistic regression. The association between the susceptibility of medicinal plants treating COVID-19 symptoms and the explanatory parameters was assessed using Pearson's Chi-square test. Cramer's Phi and V test provided insights into the nature of this association. If the outcomes suggested a significant difference at a 5% alpha level, it would imply a causal structure warranting further investigation. The significance of the findings prompts inquiries into the responsible parameters, the effect parameter, potential unmeasured causes, and their interrelationships. Binomial logistic regression was utilized to scrutinize decisions across categories, forecast the probability of choosing one option over another, and ascertain the causal aspect of the relationship.

3. Results and discussion

3.1. Results

3.1.1. Socio-economic profile of respondents

The socio-economic profile of 80 respondents was analyzed, and showed that 83.9% of the respondents belong to the Bantu sedentary groups including Zime (73.7%), Kako (6.2%) and Bamileke (3.8%), indigenous Baka (12.5%), and Bamoun (3.8%) commercial migrants. The age of the respondents ranged from 21 to 70 years, with the majority being men (62.5%). The largest group of respondents (32.5%) was between the ages of 30 and 40 years old. 45% of the respondents were married, and 92.5% of them could read and write. Out of the household heads interviewed, 50% had passed primary school, and 42.5% had passed secondary school (Table 3).

3.1.2. Ethnobotanical study

The grouping of COVID-19 symptoms was made based on the responses of the indigenous peoples and local communities in the Lomié subdivision. The five main symptoms identified are: high fever and body aches, severe headache, severe cough and cold, and runny nose.

3.1.2.1. Diversity of medicinal plants. The Lomié subdivision has a rich and diverse medicinal flora, with 43 species belonging to 39 genera grouped in 28 families that are used to treat COVID-19 symptoms. The most diverse families in terms of species were Fabaceae having 6 species and Solanaceae having 5 species. Out of the 43 species, 11 are cultivated and 32 are spontaneous (Table 4).

According to the COVID-19 symptoms that they treat, 14 species with a frequency of citation ranging from 11.5% to 55% were categorized based on the results of the frequency of citation (FC) analysis. As indicated by Table 4, the most often utilized species are *Alstonia boonei* (FC = 55%) for fever, *Aframomum* sp. (FC = 15%) for cough, *Dracaena fragrans* (FC = 15%) for headaches, and *Tricoscypha acuminata* (FC = 12.5%) for colds. With 11.1% of the recipes each, *Ageratum conyzoides* and *Myrianthus arboreus* are the plants that contribute the most to the recipes. The remaining plant species (3.7%) are represented by *Alstonia boonei, Annickia affinis,*

Table 3
Socio-economic profile of respondents.

Features		Worforce	Proportion (%)
Ethnicity	Baka	10	12.5
	Babilègue	3	3.8
	Bamoun	3	3.8
	Kako	5	6.2
	Zimé	59	73.7
Type	Men	50	62.5
	Women	30	37.5
Age	<30	15	18.8
	[30–40]	26	32.5
	[41–50]	14	17.5
	[51–60]	8	10
	>60	17	21.2
Marital status	Single	25	31.3
	Divorced	10	12.5
	Married	36	45
	Widow (er)	9	11.3
Instruction level	Informal school	6	7.5
	Primary	40	50
	Secondary	34	42.5

Table 4
Scientific and vernacular names of medicinal plants, families, frequency of citation and contribution of plants.

Scientific names	Vernacular names	Families	FC (%)	Org	Nm	Cpr (%)
***Aframomum* sp.**	Etiélé[1]; Nji[2]	Zingiberaceae	15	Lf; Fr	1	3.7
***Afzelia bipindensis* Harms**	Odouh[1]	Fabaceae	6.25	Bk	1	3.7
***Ageratum conyzoides* L.**	Anoumopor[1]	Asteraceae	32.5	Lf	2	11.1
***Aloe vera* (L.) Burm.f.**	Aloe vera[3]	Aloeceae	6.25	Lf	1	3.7
***Alstonia boonei* De Wild.**	Lomo[1]	Apocynaceae	55	Bk	1	7.4
***Annickia affinis (Exell)* Versteegh & Sosef**	Piyé[1]	Annonaceae	40	Bk	1	7.4
***Baillonella toxisperma* Pierre**	Odjoh[1]; Gio[2]	Sapotaceae	17.5	Bk	1	3.7
***Bidens pilosa* L.**	Biokoa[1]	Asteraceae	13.75	P	1	3.7
***Calamus rotang* L.**	Lo oh[1]	Arecaceae	6.25	Lf	1	3.7
***Canarium schweinfurthii* Engl.**	Scéne[1]	Burseraceae	6.25	Bk; Lf	1	3.7
***Capsicum frutescens* (L.)**	Tama[1]; Angéleka[2]	Solanaceae	5	Fr	2	7.4
***Carica papaya* L.**	Papayer[3]	Caricaceae	6.25	R; G; Lf	1	3.7
***Citrus limon* (L.)**	Napior[1]	Rutaceae	5	Fr	1	74
***Clematis texensis* Burkley**	Cou ékomo[1]	Ranuculaceae	5	Fr	1	3.7
***Cylicodiscus gabunensis* Harms**	Buluma[2]	Fabaceae	15	Bk	1	3.7
***Cymbopogon citratus* (DC) Stapf**	Adudur[1]	Poaceae	15	Lf	1	3.7
***Dracaena fragrans* (L.) Ker Gawl**	Miène[1]	Asparagaceae	15	Lf	1	3.7
***Emilia praetermissa* Mile-Redh.**	Tourchie[1]	Asteraceae	3.75	Lf; P	1	3.7
***Entandrophragma cylindricum* Harms**	Ossié[1]	Meliaceae	7.5	Bk	1	3.7
***Garcinia kola* Heckel**	Ebil[1]; Pgbwel[2]	Clusiaceae	3.75	Fr	1	3.7
***Guibourtia tessmannii* (Harms) J.Leonard**	Ebokoane[1]; Menji	Fabaceae	3.75	Bk	1	3.7
***Hylodendron gabunense* Taub.**	Lane[1]; Lando o[2]	Fabaceae	3.75	Bk	2	3.4
***Mangifera indica* L.**	Manguier[3]	Anacardiaceae	2.5	Bk; Lf	1	3.7
***Milicia excelsa* (Welw.) Benth**	Mbo o[1]	Moraceae	5	Bk	1	3.7
***Musanga cecropioides* R.Br. ex Tedlie**	Eruk[1]	Urticacaea	2.5	Lf; Bk	1	3.7
***Myrianthus arboreus* P.Beauv.**	Ngata[2]	Cecropiaceae	2.5	Bk	2	11.1
***Ocimum gratissimum* L.**	Menumo[1]	Lamiaceae	35	Lf	1	3.7
***Opuntia ficus-indica* (L.) Mill.**	Figuier	Cactaceae	2.5	Lf	1	3.7
***Pentaclethra macrophylla* Benth.**	Mbalaka[3]	Fabaceae	2.5	Lf	1	3.7
***Piptadeniastrum africanum* (Hook.f.) Brenan**	Kungu[1]; Dabema[2]	Fabaceae	12.5	Bk	1	3.7
***Pycnanthus angolensis* (Welw.) Warb.**	Kunzo[1]; Illomba[2]	Myristicaceae	12.5	Bk	1	3 .7
***Solanum lycopersicum* L.**	Tomate[1]	Solanaceae	1.25	Lf	1	3.7
***Solanum melongena* L.**	Obergine[3]	Solanaceae	1.25	Lf; Fr	1	3.7
***Solanun nigrum* L.**	Legume[3]	Solanaceae	1.25	Lf	1	3.7
***Solanum torvum* Sw.**	Bamla[1]	Solanaceae	6.25	Lf	1	3.7
***Terminalia superba* Engl. & Diels**	Ngulu[2]	Combretaceae	3.75	Bk	1	3.7
***Theobroma cacao* L.**	Cacaa a[1]	Sterculiaceae	1.25	Lf	1	3.7
***Trichoscypha aborea* (A.Chev.) A. Chev**	So oh[1]	Anacardiaceae	11.25	Bk	1	7.4
***Trichoscypha acuminata* Engl.**	Nko o[1]	Anacardiaceae	12.25	Lf	1	3.7
***Vernonia amygdalina* Delile**	Dolait[1]	Asteraceae	2.5	Lf	1	3.7
***Voacanga africana* Stapf ex Scott-Elliot**	Voacanga	Apocynaceae	7.5	Bk	1	3.7
***Xanthosoma sagittifolium* (L.)**	Tor ekaba	Araceae	1.25	Lf	1	3.7
***Zingiber officinale* Roscoe**	Gingimbre[3]	Zingiberaceae	7.5	Fr	3	7.4

Vernacular name: 1- Zimé, 2- Baka, 3- common name; FC: Frequency of citation; Org: plant organs; Bk: bark, Lf: leaf, Fr: fruit, R: root, G: seed; Nm: number of COVID-19 symptoms treated, Cpr: contribution of plants in recipes.

Table 5
Fidelity index of medicinal plants with a citation frequency of 10 or more.

Plant species	COVID-19 symptoms treated	FC (%)	Ip	Iu	FL (%)
***Aframomum* sp.**	Cough	15	10	12	83.3
Ageratum conyzoides	Fever, Cough	32.5	20	26	76.9
Alstonia boonei	Fever	55	55	55	100
Annickia affinis	Fever	40	40	40	100
Baillonella toxisperma	Fever	17.5	14	30	46.6
Bidens pilosa	Cough	13.75	11	20	55
Cymbopogon citratus	Fever	15	9	12	75
Cylicodiscus gabunensis	Fever	15	40	80	50
Dracaena fragrans	Headaches	15	75	80	93.8
Ocimum gratissimum	Cough	25	40	80	50
Piptadeniastrum qficanum	Headaches	12.5	70	80	87.5
Pycnanthus angolensis	Cough	12.5	40	80	50
Tricoschypha arborea	Colds	11.5	80	80	100
Tricoscypha acuminata	Colds	12.5	60	80	75

FC: Frequency of citation, FL: fidelity index, N_P: Number of respondents who suggest the use of the plant for the treatment of a specific disease, N: total number of respondents who mentioned this plant for any other.

Capsicum frutenscens, Citrus limon, Trichoscypha aborea, and *Zingiber officinale*, which each account for 7.4% of the recipes. Among the most commonly used plants (FC $\geq$ 11.5%), 11 species have a fidelity index above 50%, with species like *Alstonia boonei, Annickia affinis*, and *Tricoscypha acuminata* having a fidelity index of 100% for treating fever and colds. This high-fidelity index indicates their exceptional efficacy and popularity for this COVID-19 (Table 5).

The results show that *Ageratum conyzoides* is used for the treatment of three symptoms of COVID-19, while species like *Milicia excelsa*, *Alstonia boonei*, *Annickia affinis*, and *Clematis texensis* only treat one symptom (as listed in Table 6). The most commonly used plant species for treating symptoms of COVID-19 are *Alstonia boonei* and *Annickia affinis* (37.5%) for fever, *Aframomum* sp. and *Ageratm conyzoides* (18.7%) for cough, *Tricoscypha aborea* and *Myrianthus arboreus* (37.5%) and *Zingiber officinale, Citrus limon,* honey, and *Capsicum frutenscens* (37.5%) for colds, *Myrianthus arboreus* and *Zingiber officinale* (50%) and *Trichoscypha acuminata* and *Trichoscypha aborea* (37.5%) for runny nose, and *Piptadeniastrum africanum* (37.5%) for headache (Table 6).

It was noticeable that bark (43.8%), leaves (25%), the entire plant (15%), fruits (11.2%), and roots (5%) were the most common ingredients used to make herbal treatments (Fig. 2). The most used way of preparation (50%) is decoction, which is followed by spiritual (3.7%), infusion (26.3%), and maceration (20%). The most popular delivery methods are nasal (12.5%), cutaneous (18.8%), and oral (56.3%). The two least common administration routes are the rectum (7.5%) and spiritual (4.9%). The majority of medicines (85%) are produced from fresh plant parts, 3% from dried plant parts, and 12%, depending on choice, from both fresh and dry plant

Table 6
Symptoms of COVID-19, mode of treatment, frequency of recipe and frequency of recipe citation.

Symptoms COVID-19	Recipes			Parameters	
	Composition	Preparation method	Dose, dosage, duration of treatment, routes of administration	Fr (%)	Fcr (%)
Fever	Bark of *Alstonia boonei* + bark of *Annickia affinis*	Decoction or maceration in 5 l water	Drink 1 glass morning, noon and evening (3 times a day) until fully recovered	37.5	7.5
	Altonia boonei bark + *Hylodenron gabunense* bark + *Calamus rontang* leaf	Decoction in 5 l water	Drink 1 glass morning, noon and evening (3 times a day) until fully recovered	18.7	3.7
	Bark of *Entandrophrama cylindricum* + *Annickia affinis* + *Afzelia bipindensis*	Decoction in 5 l water	Drink 1 glass morning, noon and evening (3 times a day) for 14 days	10	2
	Cylicodiscus gabunensis bark + *Carica papaya* leaf + *Solanum torvum* + *Vernonia amygdalina* + *Solanum nigrum*	Decoction of bark in 5 l water	Drink 1 glass morning, noon and evening (3 times a day) for 21 days	7.5	1.5
	Cymbopogon citratus	Decoction of 2 l water	Drink the hot tea 1 glass morning and evening for 4 days	12,5	2.5
	Baillonella toxisperma + *Milicia excelsa* + *Clematis texensis* + *Opuntia ficus-indica*	Decoction	/	6.2	1.2
	Aloe vera leaf	Maceration	Drink morningand evenin for 7 days	7.5	1.5
Cough	*Myrianthus arboreus* + *Terminalia superba* + *Musanga cecropioides* + *Citrus limon*	Decoction of 5 l water	Drink 1 glass 3 times a day for 7 days	10	2
	Hylodendron gabunense + fruit of *Capsicum frutescens*	Decoction of 2 l water	Drink 1 glass morning, noon and avaning (3 times a day) for 14 days	6.2	1.2
	Bark of *Guibourtia tessmannii*	Burning with fire	Lick morning and evening until completely healed	15	3
	Bark of *Musanga cercropioides* + *Mangifera indica*	Decoction	Drink warm 1 glass morning and evening 7 days	6.2	1.2
	Aframomum sp. + *Ageratm conyzoides*	Decoction + sugar	One glass morning and evening for 5 days	18.7	3.7
	Garcinia kola fruit	Chewing	Morning and evening	162	3.2
	Bidens pilosa + *Emilia praetermissa*	/	/	8.7	1.7
	Bark of *Pycnanthus angolensis*	Decoction of 2 l water	Drink 1 glass morning and evening for one week	3.7	0.7
	Ageratum conyzoides leaf + *Ocimum gratissimum*	Grinding	/	5	1
	Zingiber officinale		Chew morning and evening for one week	3.7	0.7
	Bark + fruit of *Canarium schweinfurthii*	Decoction of 2 l water	Drink 1 glass morning, noon and evening (3 times a day) or eat the fruit	6.2	1.2
Colds	*Tricoscypha arborea* + *Myrianthus arboreus*	/	/	37.5	7.5
	Capsicum frutescens	Grinding	Introduce into the nostrils morning	25	5
	Zingiber officinale fruit + *Citrus limon* fruit + honey + *Capsicum frutescens*	Infusion for 30 min	Drink morning and evening for 7 days	37.5	7.5
Nasal discharge	*Myrianthus arboreus* + *Zingiber officinale*	/	/	50	10
	Trichoscypha acuminata + *Trichoscypha arborea*	/	/	50	10
Headaches	Leaf of *Pentaclethra macrophylla*	/	/	18,7	3,7
	Dracaena fragrans leaf + *Ageratum conyzoides*	/	/	31,2	6,2
	Bark or leaves of *Voacanga africana*	/	/	12,5	2,5
	Bark of *Piptadeniastrum africanum*	Crush and mix with a little watter	/	37,5	7,5

Fr: Frequency of recipes; Frc: Frequency of recipe citations.

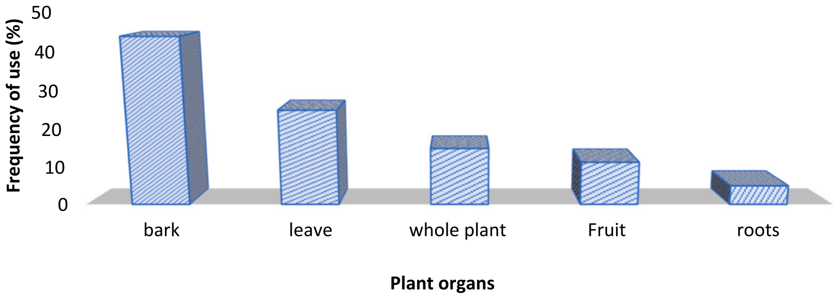

Fig. 2. Frequency of use for plant organs.

Table 7
Description of ecological parameters of species. (TM = morphological type; TB = biological type; TP = photogeographical type; TF = leaf type; TD = diaspore type; MD = dispersal mode; TFO: Forest type.

scientific names	TM	TB	TP	TF	TD	MD	TFO
Aframomum sp.	Hb	Gh	Pra	Macro	Sarco	Endo	FS
Afzelia bipindensis	A	Mgph	CG	Meso	Sarco	Auto	FP
Ageratum conyzoides	Hb	Ch	Pan	Noto	Pogo	Anemo	J
Aloe vera	Hb	Gh	Af	Meso	Ind	Auto	C
Alstonia boonei	A	Mgph	GC	Méso	Pogo	Auto	FS
Annickia affinis	A	Msph	CG	Meso	Sarco	Baro	FS
Baillonella toxisperma	A	Mgph	CG	Macro	Sarco	Baro	FP
Bidens pilosa	Hb	Ch	Pan	Noto	Pogo	Epizoo	J
Calamus rotang	L	Phgrv	Ind	Mega	Sarco	Baro	FS
Canarium schweinfurthii	A	Mgph	GC	Meso	Sarco	Endo	FS
Capsicum frutescens	SSh	Nnph	Aam	Meso	Sarco	Endo	C
Carica papaya	Sh	Mcph	Aam	Mega	Sarco	Endo	C
Citrus limon	Sh	Mcph	Aas	Micro	Sarco	Baro	C
Clematis exensis	A	Ind	Ind	Ind	Ind	Ind	FS
Cylicodiscus gabunensis	A	Mgph	CG	Meso	Ballo	Auto	FP
Cymbopogon citratus	Hb	H	Af	Noto	Ind	Anemo	C
Dracaena fragrans	Hb	Nnph	At	Ind	Sarco	Endo	J
Emilia praetermissa	Hb	Ch	At	Noto	Pogo	Anemo	J
Entandrophragma cylindricum	A	Mgph	GC	Meso	Ptero	Anemo	FP
Garcinia kola	Sh	Msph	CG	Meso	Sarco	Baro	FS
Guibourtia tessmannii	A	Mgph	GC	Meso	Ballo	Auto	FP
Hylodendron gabunense	A	Mgph	WG	Micro	Ballo	Auto	FS
Mangifera indica	A	Msph	Aas	Meso	Desmo	Antro	C
Milicia excelsa	A	Mgph	GC	Meso	Sarco	Ind	FS
Musanga cecropioides	A	Msph	GC	Méso	Sarco	Endo	FS
Myrianthus arboreus	A	Mcph	GC	Macro	Sarco	Endo	FS
Ocimum gratissimum	SSh	Nnph		Meso	Ind	Anemo	C
Opuntia ficus-indica	Sh	Ind	Ind	Ind	Ind	Ind	FS
Pentaclethra macrophylla	A	Msph	GC	Lepto	Ballo	Auto	FP
Piptadeniastrum africanum	A	Mgph	GC	Lepto	Ballo	Anemo	FS
Pycnanthus angolensis	A	Mgph	GC	Meso	Sarco	Auto	FS
Solanum lycopersicum	Hb	Th	An	Meso	Ind	Endo	C
Solanum melongena	Hb	H	Ind	Macro	Ind	Endo	C
Solanun nigrum	Hb	Ch	Cos	Meso	Sarco	Endo	C
Solanum torvum	SSh	Mcph	Pan	Meso	Sarco	Endo	J
Terminalia superba	A	Mgph	GC	Meso	Ptero	Anemo	FS
Theobroma cacao	Sh	Mcph	Aam	Meso	Ind	Anthro	C
Trichoscypha aborea	A	Msph	WG	Macro	Sarco	Endo	FS
Trichoscypha acuminata	A	Msph	WG	Macro	Sarco	Endo	FS
Vernonia amygdalina	Hb	Mcph	At	Meso	Pogo	Anemo	C
Voacanga africana	Sh	Mcph	At	Macro	Sarco	Auto	FS
Xanthosoma sagittifolium	Hb	Gh	Ind	Mega	Ind	Anthro	C
Zingiber officinale	Hb	Gh	Ind	Meso	Sarco	Endo	C

Ch: champhytes; Gh: geophytes; Th: therophytes; Phgrv: lianaceous phanerophytes; H: hemicryptophytes; Pan: pantropicals; At: Afro-tropicals; GC: Guineo-Congolese; Aam: Afro-Americas; Aas: Afro-Asiatic; CG: Central Guineo-Congolese; Cos: Cosmopolitan; An: South American Andean, Af: African; Pra: African multi-regional; Mega: megaphylls; Macro: macrophylls; Meso: mesophylls; Noto: notophylls; Micro: microphylls; Lepto: leptophylls; Ballo: ballochores; Pogo: pogonochores; Ptero: pterochores; Sarco: sarcochores; Desmo: desmochores; Epizoo: epizoochories; Endo: endozoochories; Anemo: anemochories; Auto: autochories; Antro: Anthropochories; Baro: Barochories; C: Working field; FS: Secondary forest; J: Fallow land; FP: Primary forest; Sh: Shrub; SSh: Sub-shrub; L: liana; Ind: Undetermined.

material. The species investigated in the study were classified into four types of habitats: secondary forests (41.9%), food crop fields (32.6%), primary forests (14%), and fallow land (11.5%). Trees are the most common morphological type (44.2%), followed by herbaceous plants (30.2%), shrubs (16.3%), sub-shrubs (7%), and lianas (2.3%). The plants belong to 11 phytogeographical types, with the most common being species with a Guinean-Congolese distribution (25.6%), followed by Central-Guinean-Congolese species (11.6%), and Afro-tropical species (9.3%). Species with a multi-regional distribution (2.3%), African (2.3%), and South American Andean are the least represented (2.3%) (Table 7).

The species recorded can be divided into five types of diaspore. The results show that 51.1% of species are sarcochores (totally or partially fleshy diaspores), followed by 11.6% pogonochores (diaspores with feathery or silky appendages), 11.6% ballochores (diaspores expelled by the plant itself) and 4.7% pterochores (diaspores with aliform appendages). Desmochores (hanging diaspores) are the least represented, at 2.3% (Table 7).

A total of nine modes of spread were identified. Species spread by endozoochory (a mode of plant dispersal that occurs when diaspores are swallowed by the animal, which then rejects them by defecation or regurgitation) are most represented at 32.6%, followed by 14% of species that spread by anemochory (a method of dispersing plant seeds using the wind) and 11.6% of species that spread by barochory (the dispersal of barochorous seeds by gravity alone, in which the seeds of a plant fall under the mother plant). Epizoochory (seed dispersal by transport on the plumage or fur of animals) and anthropochory (plant species whose range has been extended to different geographical areas deliberately and/or accidently by man) are the least common means of dissemination, accounting for 2.3% (Table 8).

Mesophyll leaves (leaf size between 20 and 200 cm^2) are the most represented leaf type with 51.2%, followed by 16.3% macrophylls (leaf size between 200 and 20 dm^2) and 9.3% notophylls (leaf size between 2025 and 4500 mm^2). The two least common types are microphylls (leaf size between 2 and 20 cm^2) and leptophylls (leaf size <0.2 cm^2) with 4.7% (Table 7).

The results reveal nine biological types, with 27.6% of megaphanerophytes (trees >30 m tall with shoots and aerial buds located a significant distance above ground), followed by 16.3% of microphanerophytes (trees between 2 and 10 m in height, with shoots and aerial buds a significant distance above ground) and 16.3% of mesophanerophytes (trees between 10 and 30 m in height, with shoots and aerial buds a significant distance above ground). Phanerophytic lianas (voluble plants with tendrils, spiked roots, creepers and/or props) are the least represented at 2.3% (Table 7).

3.1.3. *Vulnerability of medicinal plants*

The results indicate that 30 species that are being used to treat COVID-19 symptoms, have a vulnerability index of more than or equal to 2 and less than 2.5, making up 69.7% of the surveyed species. These species are considered the most vulnerable. *Entandrophragma cylindricum, Milicia excelsa, Myrianthus arboreus,* and *Trichoscypha aborea* with a vulnerability index of 2.4. On the other hand,

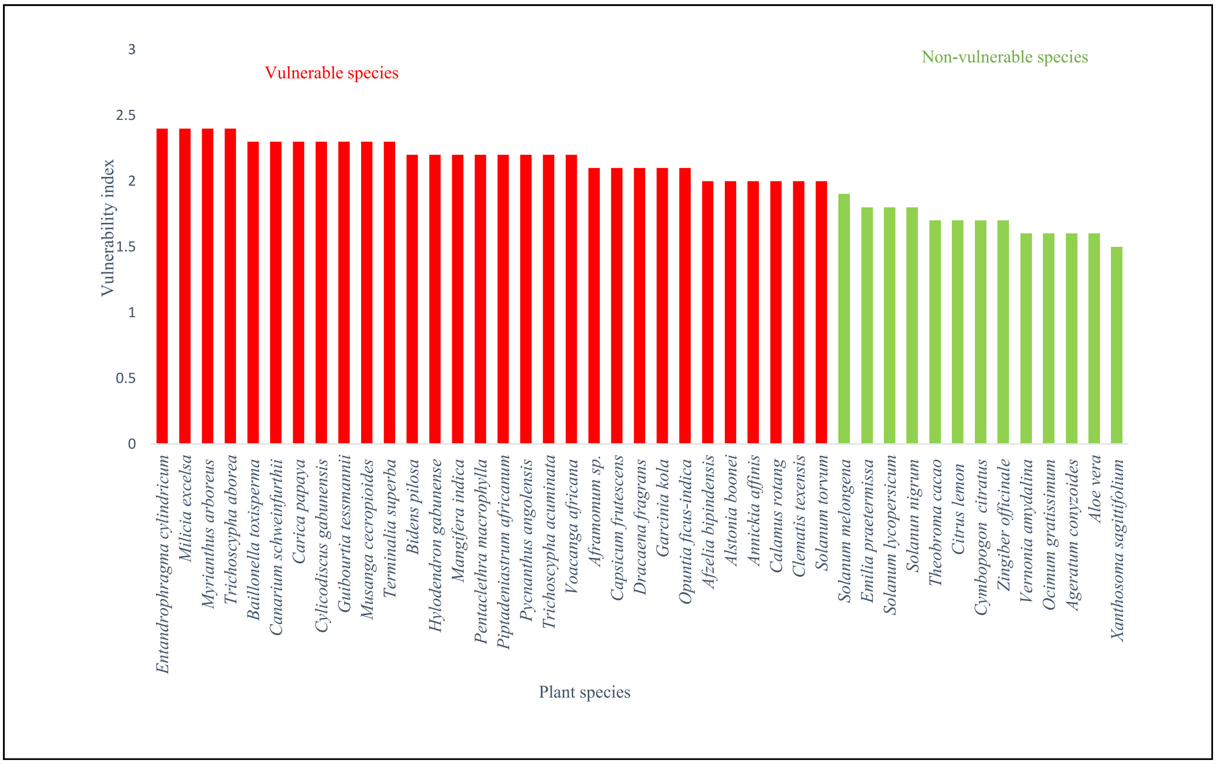

Fig. 3. Species vulnerability spectra.

30.3% of the recorded plant species are not vulnerable (Iv < 2), including *Solanum melongena*, *Emilia praetermissa, Solanum lycopersicum*, *Solanum nigrum*, *Citrus limon* and *Xanthosoma sagittifolium* is the least vulnerable species, with an (Iv = 1.5) (Fig. 3).

3.1.4. *Explanatory parameters of plants vulnerability*

3.1.4.1. *Correlation between the vulnerability and parameters.*

- Relationship between medicinal plants with a vulnerability index of 2.4 and explanatory parameters.

The multiple correspondence analysis (MCA) show that 88.1% of the vulnerability of medicinal plants with an index equal to 2.4 is explained by the factorial design composed of axes 1 and 2, which represent 63.9% and 24.2% of the total inertia, respectively. Axis 1 includes parameters such as bark (EC), decoction (DEC), cutting (CO), maceration (MA), high popularity (PE), and *Trichoscypha acuminata* (TA). Axis 2 is represented by parameters including primary forest (PF), sarcochory (Sarco), and maceration (MA) (Fig. 4).

- **Relationship between medicinal plants of vulnerability index 2.1; 2.2; 2.3 and explanatory parameters**

The results of the multiple correspondence analysis revealed that 83% of the vulnerability of medicinal plants with indices equal to 2.3, 2.2, and 2.1 is explained by the factorial design, composed of axes 1 and 2, representing 69.1% and 13.9% of the total inertia, respectively. Axis 1 includes parameters such as sub-shrub (S–Ar), maceration (MAC), harvesting (CU), dry organ (OSE), *Trichoscypha acuminata* (TAC), sarcochory (Sarco), decoction (DEC), *Pycnanthus angolensis* (PY), *Hylodendron gabunense* (HG), *Piptadeniastrum africanum* (PA) and cutting (CO). Axis 2 groups parameters such as medium popularity (PMOY), secondary forest (PF), herbaceous (H), fallow (JA), *Bidens pilosa* (BP) and high popularity (PE) (Fig. 5).

- **Relationship between medicinal plants with a vulnerability index of 2 and explanatory parameters.**

The results of the multiple correspondence analysis (MCA) show that 85% of the vulnerability of medicinal plants with a vulnerability index of 2 is demonstrated by the factors on two axes of the MCA plot, accounting for 70% and 15% of the total inertia, respectively. Axis 1 is composed of parameters such as: liana, sarcochory, *Calamus rotang* (CR), *Annickia affinis* (AA), *Alstonia boonei* (ALB), low frequency in the environment (FF), and tree (A). Axis 2 includes: secondary forest (FS), high popularity (PE), desmochory (desmo), *Clematis princess* and root (R) (Fig. 6).

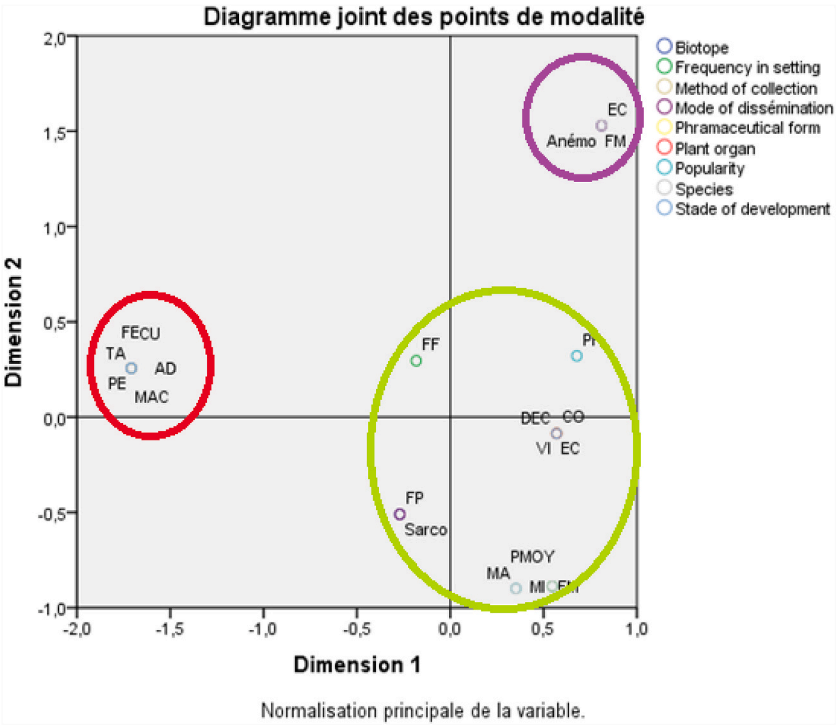

Fig. 4. MCA of medicinal plants with a vulnerability index of 2.4 and explanatory parameters.

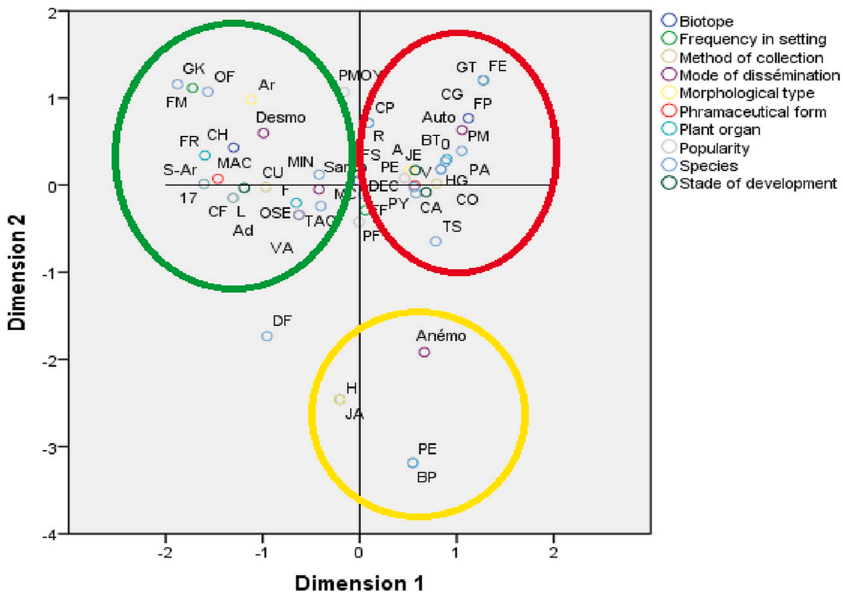

Fig. 5. Multiple correspondence analysis of explanatory parameters for medicinal plants with a vulnerability index of 2.1, 2.2 and 2.3.

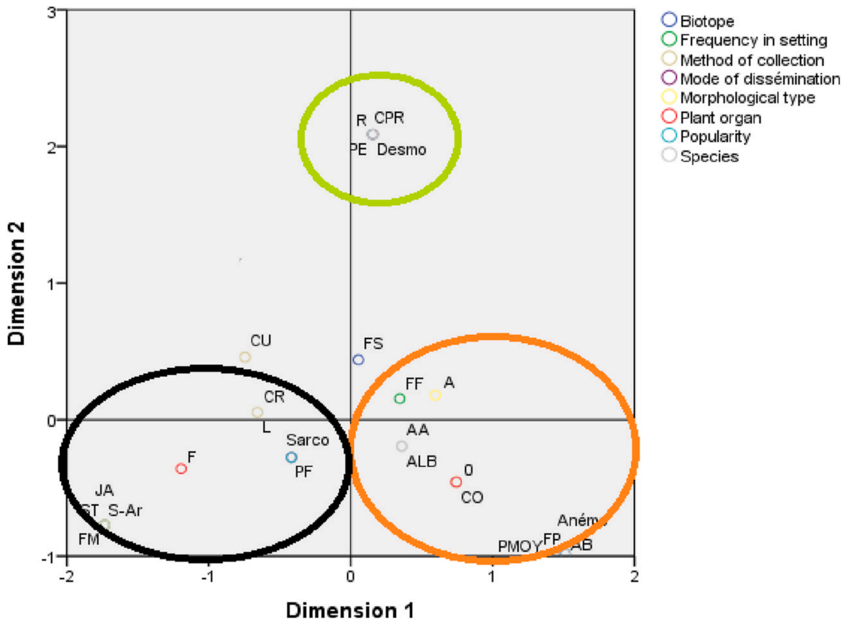

Fig. 6. Multiple correspondence analysis of explanatory parameters for medicinal plants with a vulnerability index of 2.

3.1.4.2. Qualitative parameters. The determination of the relationship between the vulnerability of medicinal plants against COVID-19 symptoms and the explanatory parameters was analyzed and a positive relationship was found. The Pearson's Chi-square test revealed a significant difference (p-value$<\alpha$) at a 5% significance level ($\alpha = 0.05$) (Table 8). A significance criterion of $\alpha = 0.05$ is not met by the Pearson Chi-square test, which yielded a p-value of 0.000. Every explanatory parameter, including popularity, frequency of species in the environment, biotope, diaspore, morphological type, plant organ, mode of collection, stage of development, and pharmaceutical form, had a symmetric measure or strength of relationship equal to 1, according to the Phi and Cramer's V test. (Cramer's V $>$ 0.7). This indicates a strong relationship between the vulnerability of medicinal plants used against COVID-19 symptoms and these qualitative explanatory parameters (Table 9).

3.1.4.3. Non-causal relationship between the vulnerability and parameters. According to the results of the binomial logistic regression analysis, there is a statistically significant relationship between the vulnerability of medicinal plants used against COVID-19 symptoms

Table 8
Pearson Chi-square test between vulnerability of medicinal plants and explanatory parameters.

	Explanatory parameters	Values	Ddl	Asymptotic significance (bilatéral)
Pearson Chi-square	Popularity	222.000[a]	90	0.000
	Frequency milieu	222.000[a]	90	0.000
	Biotope	296.000[a]	120	0.000
	Dispersa diaspores	296.000[a]	120	0.000
	Morpholocal type	370.000[a]	150	0.000
	Plant organ	370.000[a]	150	0.000
	Mode of collection	148.000[a]	60	0.000
	Stage of development	296.000[a]	120	0.000
	Pharmaceutical form	222.000[a]	90	0.000

Ddl: Degree of freedom.
[a] The cells have a theoretical size of less than 5. The minimum theoretical number of cells is .04.

Table 9
Symmetrical measures of explanatory parameters for the vulnerability of medicinal plants.

Parameter	Test	Values	Aproximate meaning
Popularity	Phi	1.732	0.000
	V of Cramer	1.000	0.000
Frequency in the environment	Phi	1.732	0.000
	V of Cramer	1.000	0.000
Biotope	Phi	2.000	0.000
	V of Cramer	1.000	0.000
Dissemination of diaspore	Phi	2.000	0.000
	V of Cramer	1.000	0.000
Morphological type	Phi	2.236	0.000
	V of Cramer	1.000	0.000
Plant organ	Phi	2.236	0.000
	V of Cramer	1.000	0.000
collear mode	Phi	1.414	0.000
	V of Cramer	1.000	0.000
Stage of development	Phi	2.000	0.000
	V of Cramer	1.000	0.000
Pharmaceutical form	Phi	1.732	0.000
	V of Cramer	1.000	0.000

and the explanatory parameters. The mode of dissemination of species by anemochory ($\beta = 1.618$; $p < 0.05$), the use of trees ($\beta = -0.963$; $p < 0.05$), shrubs ($\beta = -76.255$; $p < 0.05$), bark ($\beta = -34.592$; $p < 0.05$) and leaves ($\beta = -19.520$; $p < 0.05$) have a significant impact on the vulnerability of medicinal plants used against COVID-19 symptoms. The likelihood ratio X^2 test ($n = 43$, $X^2 = 0.635$, $p < 0.05$) shows that the model is statistically significant and has strong explanatory power. The Nagelkerke R^2 (0.899) revealed that the model explained 89.9 % of the vulnerability of medicinal plants used against COVID-19 symptoms. The model correctly classified 69.8 % of the vulnerability of medicinal plants used against COVID-19 symptoms (Table 10).

3.2. Discussion

When analyzing the gender criterion, men contribute to the majority of responses (62.5%), according to their social profile. This is because the majority of these research participants are male heads of families. Fathers passed on customary knowledge to their descendants, according to observations. These outcomes are comparable to those of Kouame et al. [17], who discovered that there was a large proportion of men (69.4%). Between the ages of 30 and 40 made up the bulk of responders (32.5%). This finding indicates that the usage of medicinal herbs is more common in those under 40. This has been made possible by the transmission of customary wisdom passed down from their predecessors. From ancestors to descendants, ancestral information is transferred on. Similar results were obtained by Inimbock et al. [8], who found a high number of respondents in the 30–40 age group. The lack of access to health infrastructure and the economic vulnerability of rural populations mean that the traditional usage of medicinal plants, passed down as an inheritance, serves as a means of cure for these populations [31].

In terms of knowledge and application of medicinal plants, the surveys found that 43 species from 39 genera and 28 families were utilized to treat COVID-19 symptoms. This indicates that the research area has a rich and varied flora. These results are consistent with prior research on medicinal herbs used against COVID-19 carried out in Africa, particularly in Cameroon. For example, Kouame et al. [17] in Ivory Coast identified 13 medicinal taxa from 13 genera and 13 families. Similarly, Inimbock et al. [8] in Cameroon identified 48 forest plant species from 22 families. Furthermore, of the species recorded, the most important families in terms of species are Fabaceae with 6 and Solanaceae with 5 taxa. Other studies conducted in Africa, Cameroon, and around the world have identified numerous other families. For instance, the most represented families in Côte d Ivoire in a study by Kouame et al. [17], were Meliaceae

Table 10
Estimation of the parameters explaining the vulnerability of medicinal plants.

Explanatory parameters	Coefficient (β)	Sig.	Wald	ddl	Exp (β)	CI for Exp. (β) 95%	
						Inferior	Supérior
Anemochore	1.618*	0.019	0.000	1	5.044	0.000	/
Tree	−0.963*	0.000	0.000	1	0.382	0.000	/
Shrub	−76.255*	0.000	0.000	1	0.000	0.000	/
Bark	−34.592*	0.01	0.000	1	0.000	0.000	/
Sheet	−19.520*	0.09	0.000	1	0.000	0.000	/
Constance	−0.836*	0.012	6.343	1	0.433	/	/
−2 Log- Likelihood	9.364						
Likelihood ratio R^2	0.635**						
Nagelkerke R^2	0.899						
Nomber of cases correctly	69.8 %						
N	43						

** significant at the 5% and 1% probability levels respectively.

(4.17%) and Zingiberaceae (3.98%). Additionally, El Alami [32] found that the Lamiaceae family is the most commonly used in Morocco for the prevention of COVID-19. In terms of biotopes, secondary forests were found to be the most species-rich (44.2%), followed by food fields (32.6%).

The results showed that bark is used in 43.8% of the recipes created with medicinal herbs. The simplicity and speed of harvesting, along with the presence of more active components, are responsible for the high usage of bark [33]. This findings differs from that of Haidara et al. [16], who discovered that leaves (24.2%) were the plant portion most frequently utilized to treat respiratory illnesses connected to COVID-19. This discrepancy may be explained by the fact that Haidara et al. [16] focused on the research conducted on medicinal plants in disturbed environments. In the study area, decoction (50%) is still the most common method of preparing traditional medicines. This is because boiling leads to a better extraction of active compounds and preservation of the medicine compared to methods such as infusion and maceration. This finding is in line with that of Inimbock et al. [8], who found that decoction (80%) was the main mode of preparation for herbal medicines. The most common route of administration for the herbal medicines used by respondents in Lomié was oral (56.3%). This is also consistent with the findings of Dibong et al. [34], who reported a high number of people using oral administration for consuming traditional medicines.

Regarding the species susceptibility to treating Covid-19 symptoms, the findings indicate that those with a vulnerability index of two or higher ($Iv \geq 2$) are deemed susceptible. The significant strain placed on natural resources is reflected in the high percentage of vulnerable species (69.7%) found. In fact, the COVID-19 pandemic has highlighted the local population's reliance of therapeutic plants. Of the thirty species that are susceptible in this investigation, four species, specifically *Afzelia bipindensis*, *Baillonella toxisperma*, *Entandrophragma cylindricum* and *Garcinia kola* have been listed as vulnerable by the IUCN Red List. These species were mentioned by Onana [14] working on taxonomic checklist with IUCN assessment for the vascular plant of Cameroon.

The species with the highest vulnerability indices are *Entandrophragma cylindricum* (Iv = 2.4), *Milicia excelsa* (Iv = 2.4), *Myrianthus arboreus* (Iv = 2.4), *Trichoscypha aborea* (Iv = 2.4), *Baillonella toxisperma* (Iv = 2.3), *Canarium schweinfurthii* (Iv = 2.3), *Carica papaya* (Iv = 2.3), *Cylicodiscus gabunensis* (Iv = 2.3), *Guibourtia tessmannii* (Iv = 2.3), *Musanga cecropioides* (Iv = 2.3) and *Terminalia superba* (Iv = 2.3). These vulnerable species are distinguished by their low abundance in natural environments and their wide use in traditional medicine [25]. The overexploitation of these species is explained by the richness of their plant organs in secondary metabolites [35]. Among these species are *Terminalia superba* (Iv = 2.3), *Carica papaya* (Iv = 2.3), *Alstonia boonei* (Iv = 2), *Annickia affinis* (Iv = 2). This converges with Betti [25] study that focused on the vulnerability of plants used as antimalarials in the Mintom sub-division where these plant species were found to be similarly vulnerable.

Furthermore, the results demonstrate that morphological characteristics, frequency of use in the environment, organ stress, and other factors all have a significant role in a plant's susceptibility [31]. This study discovered that additional factors, such as the manner of collecting, the pharmacological form, and the route of diffusion, have a substantial impact on the vulnerability of plant species in addition to the previously mentioned factors. When accounting for morphological type, trees account for 48.8% of all documented species. As a result, in addition to being utilized in natural medicine, their upright tendency makes them popular for use as construction supplies. This is especially the case for *Guibourtia tessmannii, Entandrophragma cylindricum, Cylicodiscus gabunensis, Piptadeniastrum africanum* and *Afzelia bipindensis*, whose depletion reduces their population in the natural environment.

The rate at which certain species regenerate in their native biotopes is lowered due to abusive and unchecked exploitation of these species to meet their considerable requirements. This is the case of *Annickia affinis*, *Baillonella toxisperma* and *Canarium schweinfurthii*. The majority of the plants identified in this study are used for other purposes i.e *Baillonella toxisperma* is widely used for the production of moabi oil, and *Pentaclethra macrophylla*, whose fruits are used for the production of medicines. This explains their vulnerability. Cutting and picking occur in 100% of the cases of collection. Thus, many species are debarked (*Alstonia boonei, Annickia affinis*, *Entandrophragma cylindricum, Guibourtia tessmannii, Piptadeniatrum africanum*, etc.); uprooted (*Carica papaya*, *Emilia praetermissa*, and *Bidens pilosa*). In addition, the leaves (*Ageratum conyzoides*, *Aframomum* sp., *Ocimum gratissimum*, *Solanum torvum*), fruits (*Capsicum frutescens*, *Citrus limon*, *Garcinia kola*) are picked.

Fruits, seeds, stem bark, roots, and plant organ parameter are the primary plant body components whose misuse causes detrimental ecological effects on the species. Regarding fruits, it is possible that they will have an effect on the regeneration process since, as Kokou

[36] states, the availability of seeds is one factor that maintains the capacity for regeneration. Fruit consumption on a regular basis (11.3%) thus makes species like *Garcinia kola* and *Capsicum frutescens* more vulnerable. Permanent debarking of trees is responsible for physiological disorders that impact fruiting and consequently the formation of seeds ensuring the species sustainability [26]. Indeed, the bark (43.8%) has been the most used plant organ for the preparation of traditional medicines. Species such as *Milicia excelsa*, *Baillonella toxisperma*, *Alstonia boonei* were the subject of barking. Root barks (5%) have contributed to the vulnerability of plant species. This also applies to the utilization of roots of *Carica papaya.* Traditional medicinal practices do not involve the use of seeds. The populace has, however, turned to a spectacular utilization of the entire plant (15%). In this instance, the invasive species *Bidens pilosa* was weakened in the Lomié subdivision during the COVID-19 pandemic as a result of local inhabitants' repeated and unchecked usage of it. In actuality, taking cuttings from stems and roots causes plants to die because it eliminates the cambium, which is necessary for stem and root secondary growth [25,37–39].

The frequency of therapeutic plants in the surrounding area is one factor affecting a species susceptibility. It is true that a species susceptibility may be lessened by its abundance in a given habitat. As a result, 90.7% of the therapeutic herbs used to treat COVID-19 symptoms are not well represented in the natural world. This is especially true with regard to species such as *Canarium schweinfurthii*, *Baillonella toxisperma*, *Piptadeniastrum africanum*, *Terminalia superba*, *Trichoscypha aborea* etc.

In natural medicine, the conservation of traditional recipes is a major concern in many regions of the world [40,41]. After seven days, the medicines become unfit for consumption, ineffective or even toxic due to the proliferation of pathogens [25,40,42–46]. Nonetheless, the aqueous form is most frequently utilized (98.8%) in Lomié. As a result, in order to create new medications in response to the decline of old recipes, more people are gathering medicinal plants. This makes medicinal plants in the environment more vulnerable. With a representation rate of 32.6%, endozoochory is the most prevalent mechanism of transmission. *Sarcochorous diaspores* are found in 44.2% of endozoochorous species. Similar findings were published by Ndjib [47], indicating that most plants have sarcochores. These diaspora kinds are highly capable of germination. Sarcochorous species are significant because they reflect both the importance of wildlife in forest regeneration and their forest origins [47]. Betti [25] also found a clear dominance of sarcochorous plants (66%).

4. Conclusion

In the Lomié subdivision, this study aimed to investigate the pharmacognostic standards of local communities and usage of medicinal plants by indigenous people to treat COVID-19 symptoms, as well as the plants' susceptibility to stress. The findings demonstrate that the respondents, who were primarily leaders of communities, were aware of the COVID-19 symptoms, which include fever, headaches, runny nose, coughing, and high fever. The results showed that these symptoms are treated by 43 species from 39 genera classified in 28 groups. The plants that were most frequently utilized were *Dracaena fragrans* and *Piptadeniastrum africanum* for headache*, Alstonia boonei* and *Annickia affinis* for fever, *Tricoscypha acuminata* for colds, *Aframomum* sp. and *Ageratum conyzoides* for cough. The study also revealed that bark was the most frequently used plant organ and cutting and collecting were the main modes of harvesting. The aqueous form was the pharmaceutical form which were abundantly used. However, these species were poorly represented in the environment and their vulnerability was high, with 69.7% of the species being classified as vulnerable. The findings demonstrated a robust causal connection between the nine continuous and discontinuous explanatory parameters and vulnerability. The vulnerability of these therapeutic plants was shown to be significantly impacted by the explanatory parameters, as demonstrated by the binomial logistic regression model, which validated this causal association. The study emphasized the need for conservation efforts for the most vulnerable species, such as *Entandrophragma cylindricum, Milicia excelsa, Myrianthus arboreus* and *Trichoscypha aborea*, with vulnerability indices of 2.4 (IV = 2.4). The results of the study underline the need to integrate ethnomedicine and ethnobotanical studies at the interface of scientific policy. The aim of this is to promote the traditional knowledge that has been utilized in the fight against COVID-19 and developing diseases. Complementary specialized research for drug discovery are included in this valuation in the context of the Nagoya Protocol's implementation. These findings further emphasize the necessity of educating and enlightening the local populace about the sustainable management and domestication of particular herbal remedies. In fact, conservation efforts will encourage species regeneration, allowing both current and future generations to profit from the benefits of genetic resource utilization. The study did not include phytochemical analyses of the medicinal plants identified. It will be important to identify the secondary metabolites of these plants in future work.

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Data availability statement

The data associated with this study has not been deposited in a publicly accessible repository. Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Karimou Ngamsou Abdel: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **William Armand Mala:** Visualization, Validation, Supervision, Methodology, Conceptualization. **Pierre Marie Chimi:** Visualization, Validation, Methodology, Conceptualization. **Forbi Preasious Funwi:** Visualization, Validation. **Constantin Engoulou:** Visualization, Validation. **Joseph Achille Messi Effa:** Visualization, Validation. **Michele Elodie Kouoguem Kamdem:** Visualization, Validation. **Fabrice Nzoyeuem Djonko:** Visualization, Validation. **Ulrich Landry Fokoua:** Visualization, Validation. **Samuel Brice Adounga:** Visualization, Validation. **Marie Marguerite Mbolo:** Visualization, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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