ETHNOBOTANICAL SURVEY AND AGRO-MORPHOLOGICAL CHARACTERIZATION OF GINGER (*Zingiber officinale* ROSC., ZINGIBERACEAE) CULTIVARS IN SOUTH BENIN

ABSTRACT

Ginger (*Zingiber officinale* Rosc., Zingiberaceae), a cultivated annual herbaceous plant is one of the most important spices consumed in the world with many medicinal properties. It is an income-generating plant for its production. This study aims to document endogenous knowledge on speculation as well as an agro-morphological characterization in order to make it better known and to reveal its potential to the whole world. The ethnobotanical data obtained by a semi-structured survey conducted from a questionnaire in six (06) municipalities in southern Benin made it possible to determine the local taxonomy of Ginger, the cultural practices and the different uses of the species. Ginger has been introduced in Benin for decades and in all the area study. The local names for the species as well as its uses, vary according to locality. As for the agro-morphological characterization, a complete random block device composed of five sub-plots was used. The experimental data allowed us to obtain three classes with all the accessions collected. Ginger cultivation is widespread in the study area with production on a small area. The cultivation techniques adopted do not follow any defined technical itinerary and the production tools are often rudimentary. The cultivation of ginger is therefore limited despite its multiple medicinal and economic potential. The institutions in charge of agriculture do not have data concerning the cultivation of ginger in southern Benin.

Keywords: southern Benin, ethnobotany, endogenous knowledge; ginger cultivation, technical route.

INTRODUTION

In Benin, agriculture is the main source of livelihood and creation of national economic wealth [1]. According to (Houngbo) [2], the agricultural sector occupies a key place in the economy of countries and contributes to the development of populations. Statistics from (INSAE) [3] show that in Benin, agriculture employs 70% of the working population and contributes 32.2% to the country's Gross Domestic Product (GDP), of which plant production accounts for three quarters [4]. Despite its importance, the situation of Beninese agriculture remains worrying. Thus, in 2011, a Strategic Plan for the Recovery of the Agricultural Sector was created with the aim of contributing to growth and food security through efficient

production and sustainable management of farms. To achieve this objective, special attention is then accorded to thirteen agricultural sectors [1]. But it should be noted that apart from these sectors, there are important speculations on the food, medicinal and economic plans. This is the case of ginger, a culture totally left behind by agricultural development policies long before the agricultural sector recovery policy of 2008 which does not even take it into account.

This means that at the level of the Departmental Directorates of Agriculture, Livestock and Fisheries (DDAEP) and the Territorial Agricultural Development Agencies, there is no data concerning it. The observation is the same at the level of the affiliates in charge of popularization and even the National Institute of Statistics and Economic Analysis in charge of statistical data at the national level.

Thus, more than 80% of the world's population uses plant essences to deal with their health problems [5]. Among medicinal plants, ginger occupies a prominent place in ancient and modern practices [6] and is therefore a real focus of interest in the food industry and in pharmacology. Apart from its medicinal benefits and culinary, it is of great economic importance throughout the world because of the profits made by those who produce it [7].

Its African production amounts to around 200000t/ha; 12% of world production. Nigeria is the leading African country producing ginger with 90,000t over an area of 174,000ha [7].Natural products are the most important source for drugs and drug discovery. The WHO estimated that about 65% of the World’s populations are mainly relying on natural products derived from plants for their primary health care systems and most of them are from developing countries, the remaining 35% are mostly from developed courtiers who are also used natural products indirectly to maintain a good health [8]. Among the plant species used for medicinal purposes, is the ginger. Indeed, of Indian origin, ginger (*Zingiber officinale* Rosc, Zingiberaceae) is one of the most widely used spice plants in the world. Ginger belongs to the Zingiberaceae family which are perennial monocots. As such, it is a tropical herbaceous plant that is widespread throughout the world [9]. Its rhizomes are used as condiments in the kitchen and also in medicine to treat illnesses such as coughs or to reduce toxin in the body [10]. Ginger has important medicinal qualities (fight against motion sickness, nausea and vomiting related to pregnancy, prevention of cardiovascular diseases and certain cancers) [11]. It is used as a potential anti-inflammatory, antithrombotic and antibacterial agent [12, 13]. In Benin, the cultivation of the species is weak on a small area. Therefore, a promotion of production in Benin would provide a highly income-generating activity and a source of economic growth for the country. Failure to take ginger into account by agricultural development policies could lead to the losing of genetic diversity.

To this end, it is necessary to invite the political actors, in particular those in charge of agriculture, to take an interest in this species. This will therefore require the provision of

convincing information to them. Thus, in a better approach to documenting and enhancing the nutritional, therapeutic and agricultural assets of this species, it therefore appears crucial to identify, document and characterize the ginger cultivars of the different growing areas in southern Benin.

MATERIALS AND METHODS

Study area

The collection of ginger accessions and the ethnobotanical study of the plant took place in the subequatorial zone of Benin. This area benefits from an annual rainfall varying between 950 and 1400 mm [1]. The study was carried out in six (06) municipalities in southern Benin: Klouékanmè (department of Couffo), Bohicon, Covè and Zagnanado (department of Zou), Abomey Calavi (Atlantic department) and Kétou (Plateau department) (Fig. 1). The exploration of these municipalities was possible thanks to the directives of some Territorial Agricultural Development Agencies (ATDA) and the municipal agricultural cells of the prospected municipalities.

As for the trial for agro-morphological characterization, it was conducted in the commune of Kétou (latitudes 7°10; 7°41’17" and longitude 2°24'24" ; 2°47'40") characterized by a low altitude plateau relief (between 100 and 200 m), soils of the tropical ferralitic and ferruginous type, a tropical climate with a bimodal rainfall regime with two rainy seasons and two dry seasons. . The average annual rainfall is 1073 mm in 65 days favoring the production of crops such as corn, cassava, beans, pigeon peas, etc. It brings together several ethnic groups such as the Nago, the Yoruba, the Fon, the Mahi etc.

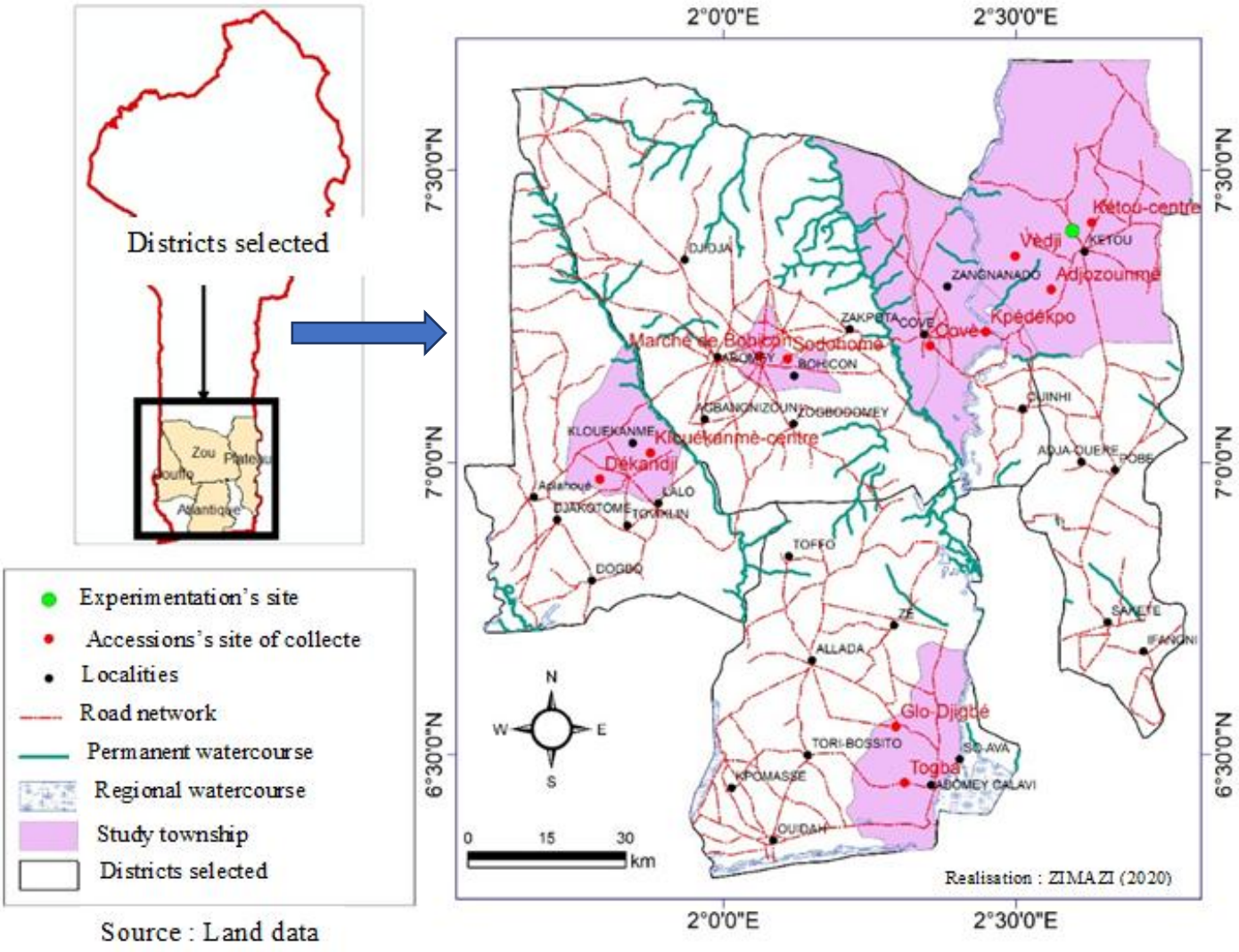

Fig. 1. Map of Benin showing the study area.

Sampling and data collection

Ethnobotanical data

Ethnobotanical study was carried out in the communes in the south of Benin. Before the actual survey, the sample size was determined through a preliminary survey in each commune. This exploratory phase was carried out on 15 people chosen at random in each municipality to estimate the proportion p of people who know and use the species. The sample size n was then calculated based on the formula of [14]:

$$n = \frac{(U_{1-\alpha/2})^2 x\, p(1-p)}{d^2}$$

With:

n, the size of the sample to be considered;

p, the proportion of people who know and use *Zingiber officinale*;

U1-α/2, the value of the normal random variable for a risk α (α = 0.05; U1-α /2 = 1.96) and

d, the expected margin of error of any parameter to be calculated, which we set at 5%.

The survey is based on a questionnaire developed for semi-structured interviews according to [15]. The Respondents are aged between 16 and 75 (age group generally having reliable knowledge of the use of the species). The information collected focused on the cultivation practices and forms of use of *Z. officinale*.

The villages are selected after an exploratory survey and with the help of agents from the communal agricultural cells. The criteria for choosing the villages was solely the production of ginger within them and taking great account of their accessibility throughout the season. The data was collected through individual interviews using a questionnaire. This questionnaire allowed us to collect information relating to the producers surveyed, in particular gender, age, experience in agricultural activities and, on the other hand, information relating to the cultivation of ginger. These were essentially: the cultivars, the local names, the characteristics of the plant (color, shape, inflorescence), the characteristics of the rhizomes (color, shape, color of the flesh, size), the yield of the different cultivars, the duration of cycle, cropping systems (association, rotation, etc.), obtaining seeds, different uses or forms of development, the parts exploited, existence of private or State structures for the promotion of cultivation. Samples of the rhizomes of the different cultivars were taken during the surveys. In this study, in addition to producers, were taken into account the traders, users and traditional healers who use it.

Agro-morphological data

During the ethnobotanical survey, the samples of ginger are collected as a rhizome from the study area. These rhizomes served as seed for the trial. The device used is a completely random block device (BAC) or a total randomization device. The planting of the rhizomes was carried out on November 04, 2020 with three (03) repetitions in order to carry out their agro-morphological characterization. This planting takes place 1 hour after watering the plot on sandy soil with 50L of water. Rhizomes weighing between 10 and 15g and comprising 3 to 4 eyes each were planted. The total area of the plot is 14m^2. It is subdivided into six (06) sub-plots. The sub-plots have different areas. This difference in area is due to the variation in the amount of accession collected from one municipality to another. The pockets are dug to a depth of 08cm and between pockets, there is a distance of 15 cm. The sub-plots are separated from each other by a distance of 30cm. After the harvest, nine (09) quantitative and qualitative variables (Table 1) are collected for the agro-morphological characterization [16].

The measurement of quantitative variables was carried out on three (03) rhizomes randomly taken from each accession.

Table 1. Agro-morphological variables

Quantitatives variables	Codes	Units	Quantitatives variables	Codes	Observations
Rhizome length	RHL	cm	Rhizome skin color	RhSC	Color
Rhizome width	RHW	cm	Rhizome flesh color	RhFC	Color
Rhizome thickness	RHT	cm	Rhizome finger type	RhFT	Short/long
Rhizome weight	RhW	g	Type of rhizome stripe	TyRhS	tight/loose
			rhizome fiber density	RhFD	Dense/loose

Data analysis

Ethnobotanical data

The people surveyed were classified by socio-cultural group, gender and age group. The frequencies of citation of the types of cultural practices are calculated. From the local names, it was determined the local taxonomy of ginger in the study area in southern Benin. The diversity of cultural practices of the species is assessed. The information collected on the

uses of the rhizome of the species was used to determine the Reported Use Value (RUV) in order to assess the level of local knowledge of the respondents on the use of the species [15]. This ethnobotanical index, which represents the total number of uses reported by a respondent, is calculated by socio-cultural group, by age category and by gender (sex) using the following formula:

$$RUV = \frac{NU_t}{N}$$

With NUt, the total number of uses reported by all respondents in a given category and N, the total number of respondents considered.

In order to test the variation of uses within ethnic groups, age groups and gender, the Reported Use Value mean was subjected to a one-way analysis of variance (ANOVA) and a comparison test of more than two the Reported Use Value using Minitab_16 (Motorola Quality Companion by Minitab, 2010) and Statistica6.1 (Stat Soft, 2001) software.

Agro-morphological data

The statistical analyzes was carried out with the average values obtained by accession. For each accession, the different qualitative characters were synthesized by repetition; which made it possible to determine the appropriate qualitative character. For the quantitative characters, the reported use value obtained by accession was calculated on the basis of the values of the three rhizomes randomly taken by accession. These values were used for the descriptive statistics of the accessions.

RESULTS

- **Locale taxonomy of *Z. officinale* in southern Benin**

The ginger, known by the scientific name of *Zingiber officinale* is a species well used by local people who use these rhizomes for many purposes. Thus, these populations hold several designations of the species. These vernacular names vary from one ethnic to another and are based on well-defined criteria (Table 2). The Fon, the Goun and the Mahi call it “Dotèh” which means “subsoil culture”. As for the Adja, they call the species “Goumè takoui” to mean “soil pepper”. While it is called "Ata ilè" by the Nago, which also means "ground pepper".

Table 2. Local names of *Z. officinale* in southern Benin

Ethnicity	Vernacular names	Significations

Adja	Goumètakoui	Peper of soil
Fon	Dotèh	Crop of soil
Goun	Dotèh	Subsoil crop
Mahi	Dotèh	Soil crop
Nago	Ata ilè	Peper frome the ground

- **Cultural practices of *Z. officinale***

The cultivation practices of *Z. officinale* relate to the type of cultivation soil, the type of crop and the mode of nutrition of the plant. About the type of soil on which the species is grown, the majority of respondents grow ginger on covered ground and on ridges. The species is more cultivated in pure culture, in rotation and without fertilizer (Figure 2).

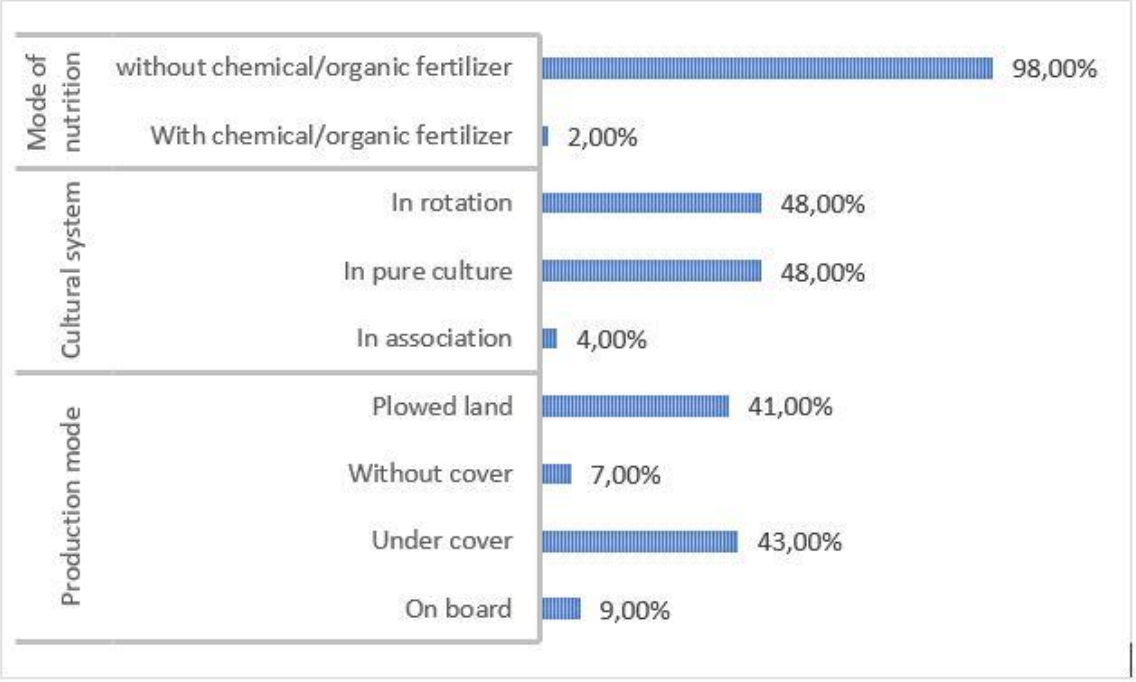

Fig. 2. Frequency of citations of *Z. officinale* cultivation practices

- **Diversity of uses of *Z. officinale***

Zingiber officinale is used in 15 uses in southern Benin with a predominance of the use of the species in sauce and in frying (Fig 3). The Reported Use Value (RUV) vary within the ethnic groups from 2.82 (Nago) to 7.15 (Fon) and show that in southern Benin, it is the Fon who generally hold more of knowledge about the species (Fig 4). People belonging to age groups [30; 60] and [60; 75] have more knowledge about the use of *Z. officinale* with the reported use value of 6.94 and 7.27 respectively, unlike those whose ages are between 16 and 30 years old have a relatively low RUV of 3.83. Within the gender, women apparently hold more knowledge in the use of the species (RUV = 6.09) than men (RUV = 5.75) (Fig 5).

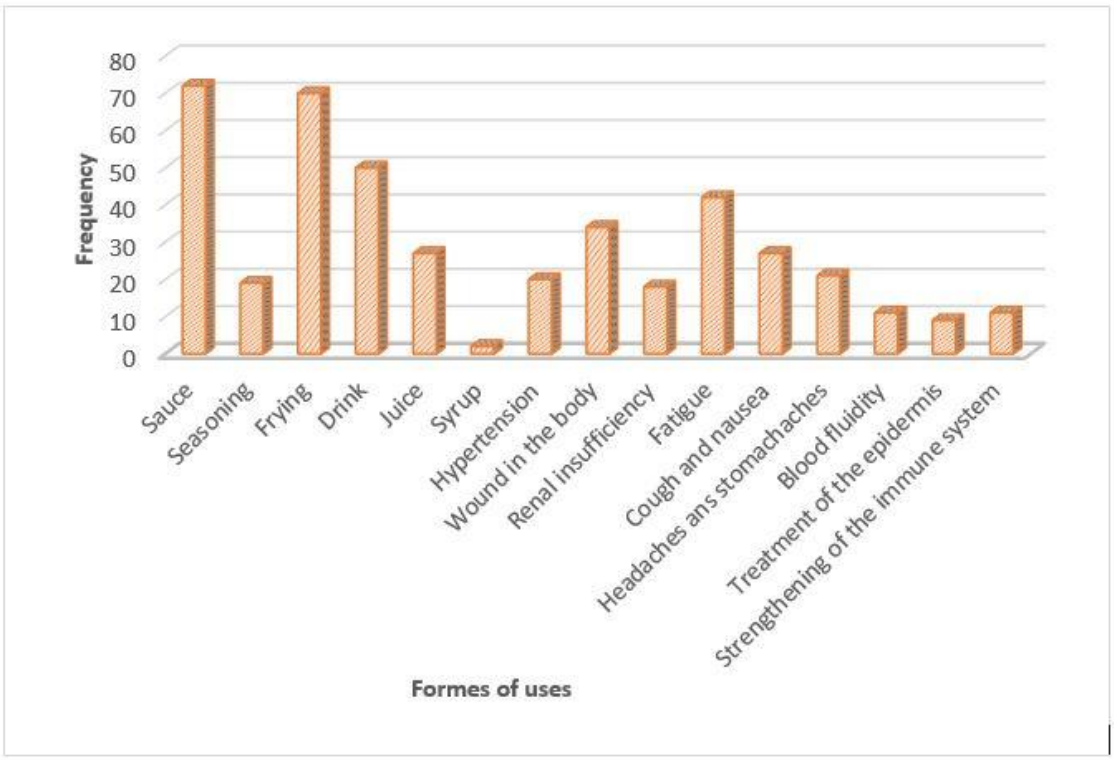

Fig. 3. Frequencies of forms of use of *Z. officinale*

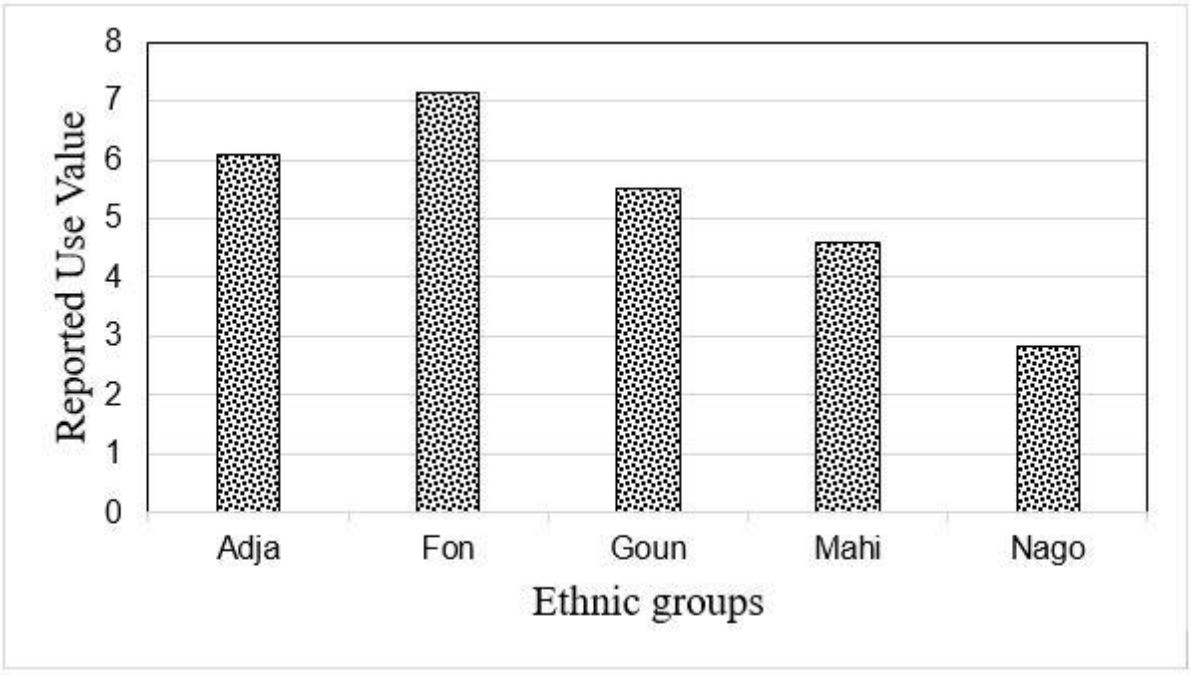

Fig. 4. Variation of the Reported Use Value according to ethnic groups

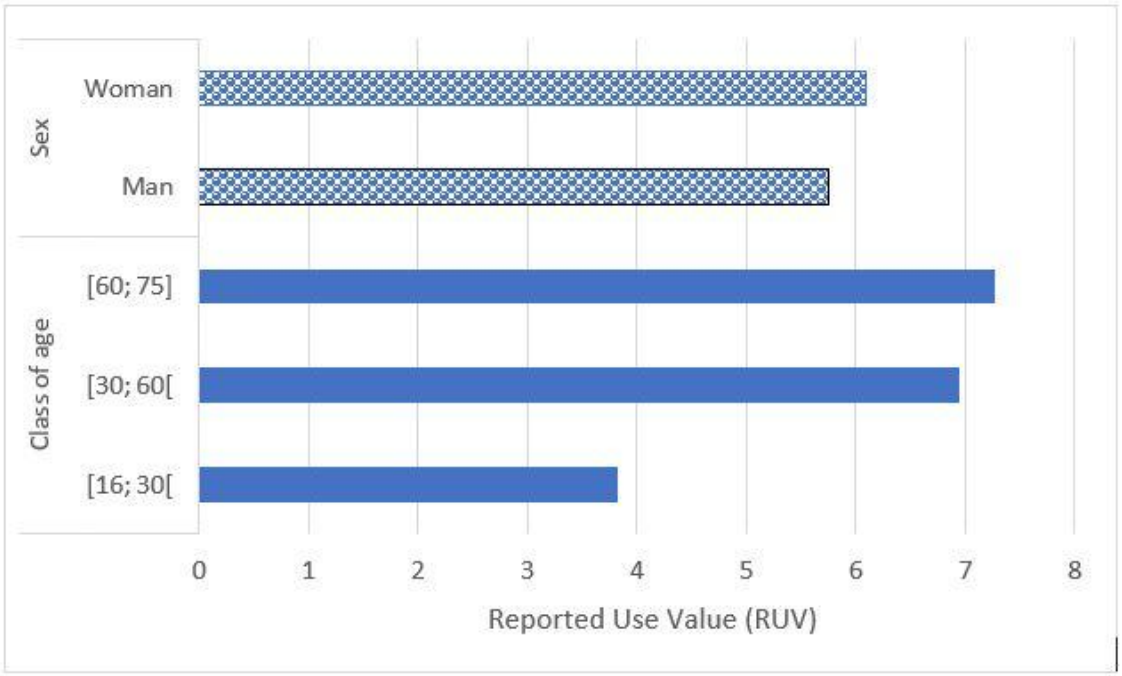

Fig. 5. Variation in the Reported Use Value within gender and age group.

The analysis of variance (ANOVA) based on the mean of the Reported Use Value (RUV) within ethnic groups and age classes showed that the variation in uses of *Z. officinale* is highly significant within age classes and very highly significant within ethnic groups (Table 5).

Table 3. Analysis of the variance of the average value of use within ethnic groups and age groups

Factors	Degree of freedom	Sum of squares	Squares mean	Fisher value (F)	Probability (P)
Ethnic	4	3208,2	802,1	22,77	0,000***
Age group	2	855	427,5	7,23	0,002**

Numbers with two stars (**) have a highly significant mean and those with three stars (***) have a very highly significant mean.

In order to determine the statistical difference between the Reported Use Value within the gender, a comparison test of two **of** the Reported Use Value was performed. The probability associated with this test (P=0.002) being less than 0.05, we reject the null hypothesis and we conclude statistically that the Reported Use Value observed in women and that of men are different. Moreover, this probability is between 0.001 and 0.01: there is therefore a highly significant difference between the RUVs within the gender (Table 4).

Table 4: Result of the comparison test of two means of RUVs **within the genus**

	Number of uses	Mean	Standars deviation	Standard error	Probability
RUV-woman	15	22.7	16.4	4.2	0.002**
RUV-man	15	6.13	5.19	1.3	

** highly significant mean

Table 5. Descriptive statistics of the quantitative variables used

	N assets	Mean	Median	Sum	Minimum	Maximum	Variance	Standard deviation	Error
RHL (cm)	29	7.80345	7.50000	226.3000	4.400000	12.9000	5.1782	2.27557	0.422562
RHW (cm)	29	2.05862	2.00000	59.7000	1.400000	3.4000	0.2104	0.45866	0.085171
RHT (cm)	29	2.05862	2.00000	59.7000	1.400000	3.4000	0.2104	0.45866	0.085171
RhW (g)	29	33.03448	26.00000	958.0000	9.000000	155.0000	928.6059	30.47304	5.658701

1- Agro-morphological variability of accessions

The preliminary analysis of the quantitative data using the Statistica6.1 software (StatSoft, 2001) gave rise to descriptive statistics for the different accessions. The result obtained is recorded in Table 5. In this table, the accessions collected, as a whole, have an average length of 7.80345cm; an average width and thickness of 2.05862 and an average weight of 33.03448.

These analyzes also made it possible to establish a histogram and a theoretical normal curve for each of the quantitative characteristics of the rhizome. Figures 6, 7 and 8 presents respectively the histogram and the theoretical curve of the weight of the rhizome, its thickness, and its length

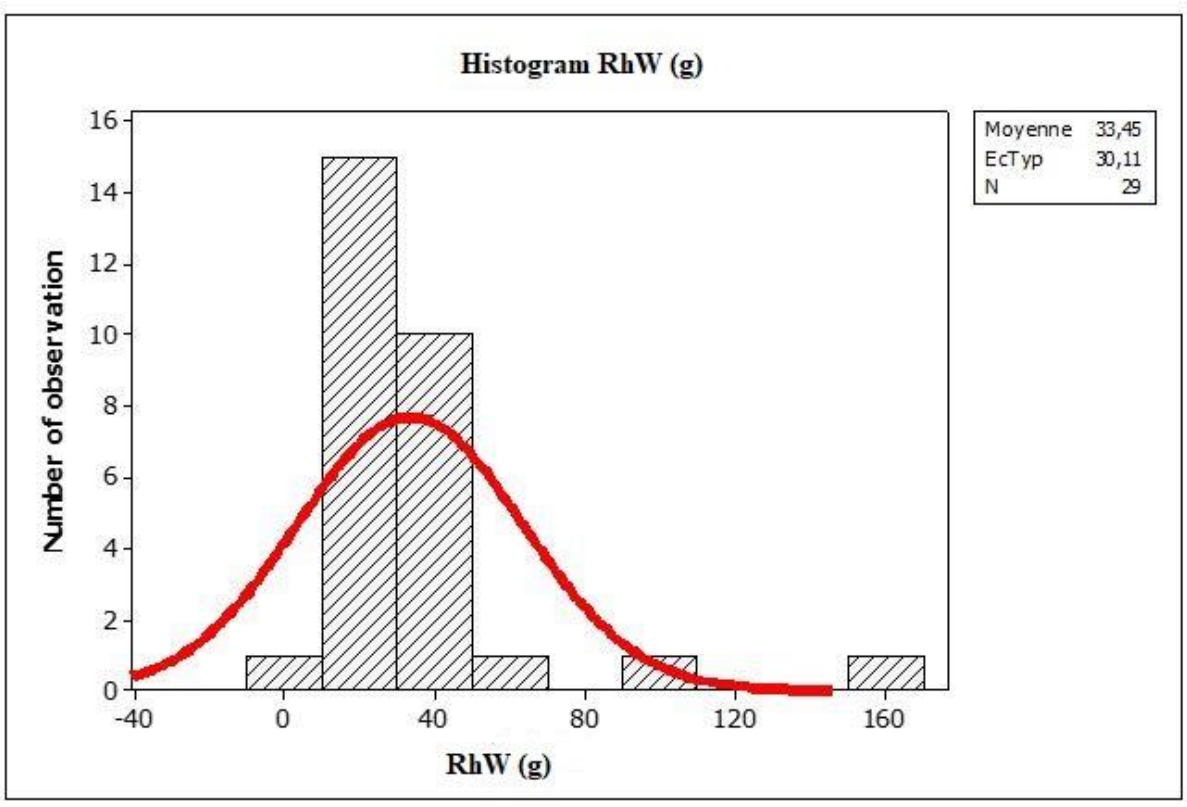

Fig. 6. Histogram and theoretical normal curve of rhizome weight

The figure 6 presents the number of observations according to the weight class of the rhizome. It emerges from the analysis of this figure that the weight of the rhizomes is between [0; 160]. The majority of rhizomes have a weight between 0 and 20g. The theoretical normal curve increases from 0 to 30 where it reaches its peak. It then decreases from 40 to 100 and becomes constant from 120 to 160. Note that the peak of the curve corresponds to the average weight of the accessions. It was then deduced that the rhizomes of the accessions are in terms of weight between 20 and 40g.

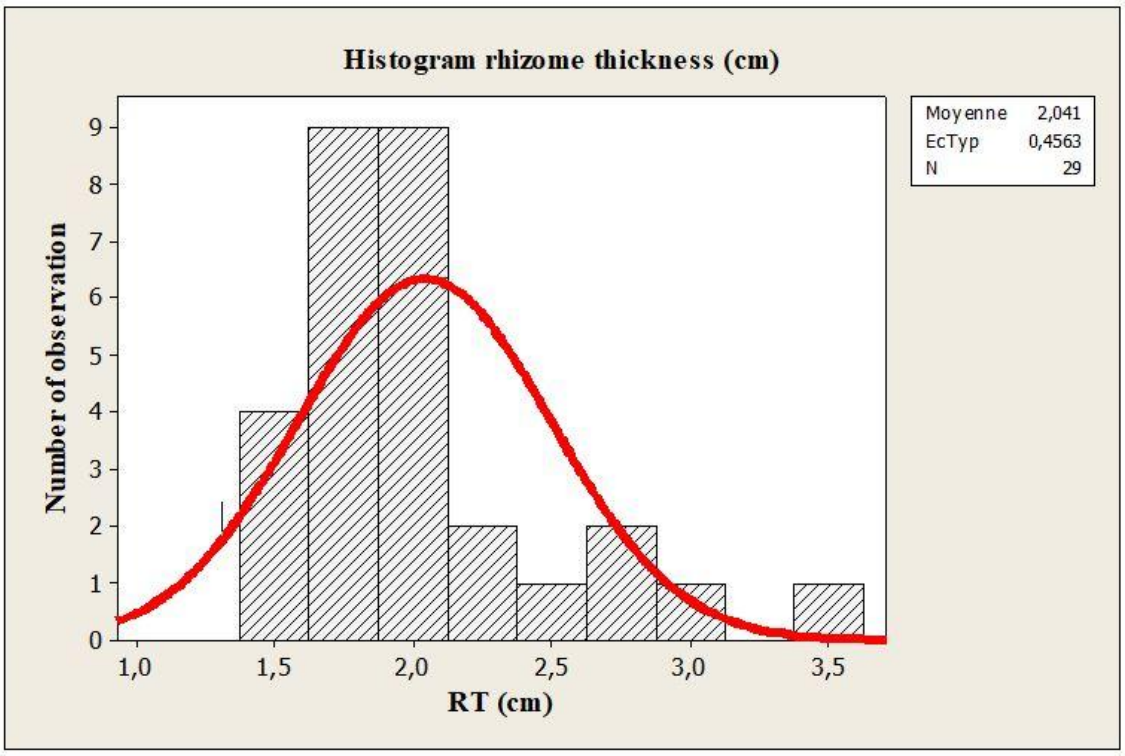

Fig. 7. Histogram and theoretical normal curve of rhizome thickness

The figure 7 translates the thickness of the rhizome according to the number of observations. It emerges from the analysis of this figure that the thickness of the rhizomes is between [0; 3.1]. Most of the rhizomes are between 0 and 3 cm thick. The theoretical normal curve increases from 0 to 2 where it reaches its peak. It then decreases from 2.5 to 3 and becomes constant from 3.5. Note that the peak of the curve corresponds to the average thickness of the accessions. It was then deduced that the rhizomes of the accessions are in terms of thickness between 1 and 3 cm.

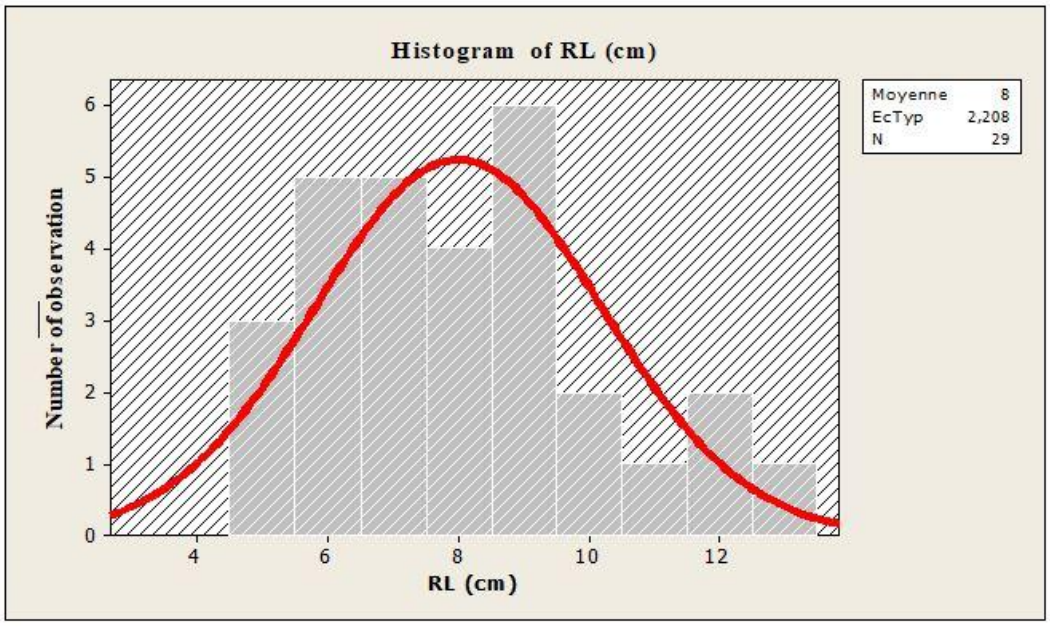

Fig. 8. Histogram and theoretical normal curve of rhizome length

The figure 8 is that relating to the length of the rhizome. It translates the length of the rhizome according to the number of observations. It emerges from the analysis of this figure that the length of the rhizomes is between [0; 12]. The majority of the rhizomes are between 2 and 12 cm. The theoretical normal curve increases from 0 to 8 cm where it reaches its peak. It then decreases from 8.5 to 12 and becomes constant from 12. Note that the peak of the curve corresponds to the average length of the accessions. It was then deduced that the rhizomes of the accessions are in terms of length between 0 and 8 cm.

From all the above, it can be noted that the cultivars obtained in the study area are mostly similar.

Clustering of accessions based on quantitative and qualitative variables

A hierarchical classification of the ginger accessions studied, carried out with Ward's aggregation criterion from the adjusted mean values of the variables of the analysis of variance, leads to the dendrogram in figure 9. The analysis of this dendrogram made it possible to differentiate three (03) main groups by putting the truncation at an aggregation distance of 100. Group I (GI) comprises 2 accessions, one (01) from Togba and one (01) from Glodjigbé. As for group II (GII), it is composed of 13 accessions including two from Glodjigbé, two (02) from Togba, five (05) from Kpédékpo, three (03) from Covè and one (01) from Kétou. Group III (GIII) is made up of 14 accessions including one (01) from Glodjigbé, (05) from Bohicon, three (03) from Kétou, one (01) from Covè, three (03) from Klouékanmè and one (01) from Kpédékpo. All the classification is represented on the dendogram of the figure 9.

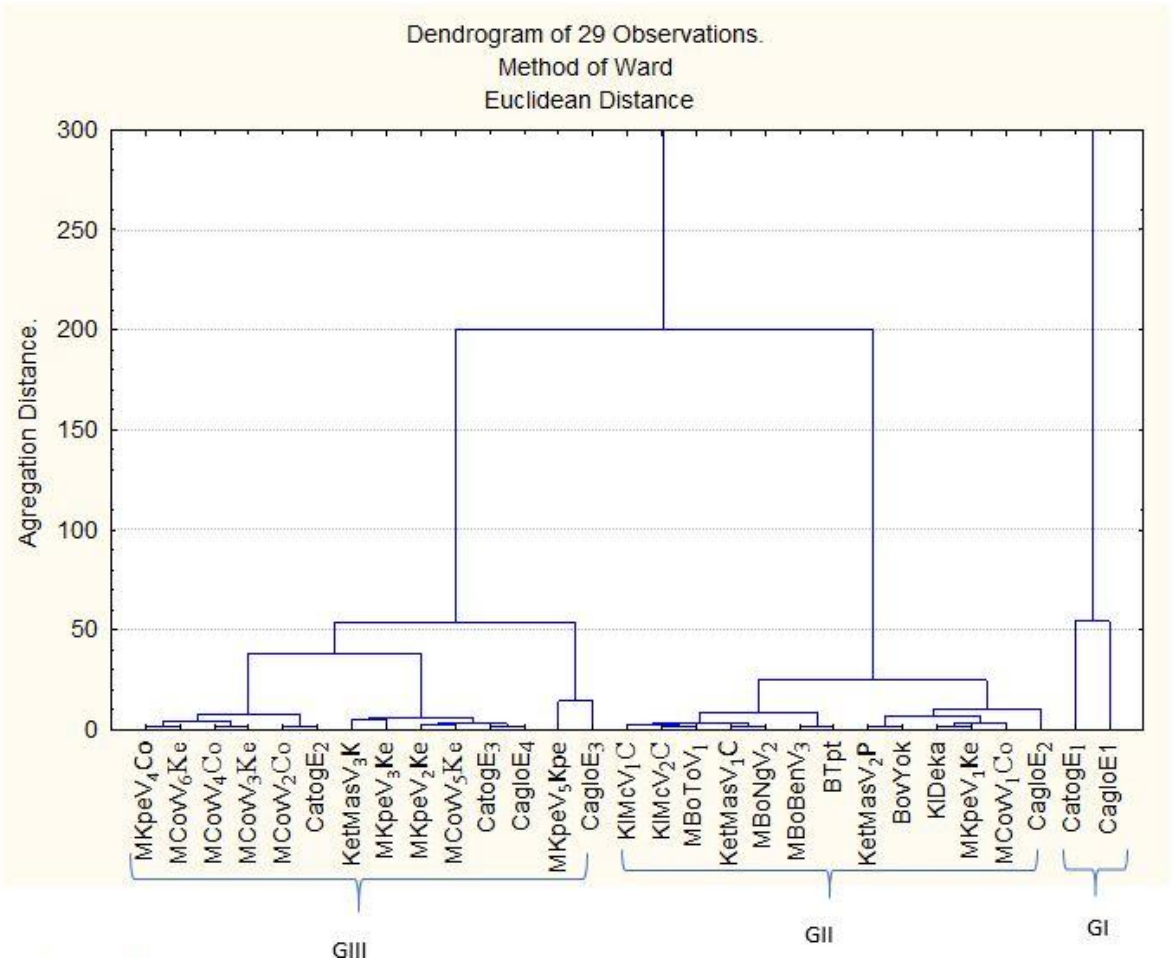
Dendrogram of 29 Observations.
Method of Ward
Euclidean Distance
Agregation Distance.
300
250
200
150
100
50
0
MKpeV4Co
MCovV6Ke
MCovV4Co
MCovV3Ke
MCovV2Co
CatogE2
KetMasV3K
MKpeV3Ke
MKpeV2Ke
MCovV5Ke
CatogE3
CagloE4
MKpeV5Kpe
CagloE3
KlMcV1C
KlMcV2C
MBoToV1
KetMasV1C
MBoNgV2
MBoBenV3
BTpt
KetMasV2P
BovYok
KlDeka
MKpeV1Ke
MCovV1Co
CagloE2
CatogE1
CagloE1
GIII
GII
GI

Fig. 9. Ascending hierarchical classification of 29 accessions of ginger from southern Benin according to Ward's aggregation criterion.

- **Characterization of groups**

The different groups obtained have different characteristics. The 2 accessions of group I have as common characteristics the color of the skin and the flesh of the rhizome. Group II is made up of 13 accessions having as common characteristics the flesh color of the rhizome and the type of toe (short). As for group III, it consists of 14 accessions with the common characteristics the color of the flesh of the rhizome, the density of the fiber and the type of streak. In conclusion, in southern Benin, there are three ginger cultivars following the agro-morphological plan in production and for sale.

DISCUSSION

Ethnobotanical variability

The ethnobotanical Survey carried out in the field made it possible to question 102 people who use ginger. The total number of uses is 15. Similar uses have been observed by [16] in countries of the sub-region such as Burkina Faso, Côte d'Ivoire and Nigeria. Among users, those classified in the age category [60, 75] have more knowledge about the uses of ginger. This is explained by the fact that the elderly holds a good part of the ancestral knowledge which is part of the oral tradition. Most of them are women with the Reported Use Value of 6.09 compared to men (5.75). This observation can be explained by the fact that the cultivation of ginger is mainly an activity of women. Concerning the habitat, the people who use ginger are located throughout the studied area but the Reported Use Value within the ethnic groups show that in southern Benin, it is the Fon who generally have more knowledge about the species. This may be because the study area is Fon dominated. As for the local taxonomy, ginger has different names (dotèh, atailè and goumètakoui). This is explained by the diversity of languages in the study area. The name gnamankou in the local Dioula language is widespread in Burkina Faso, Côte d'Ivoire and Mali [16]. The names are sometimes related to the size of the rhizome or the feeling of warmth that the rhizome gives to the tongue. The most popular cultivars in these areas are those whose rhizome has short fingers because they have a very pungent taste [16].

Cultivation practices have shown that the crop is either produced on flat or ridge ploughing, in association or pure culture, in rotation, under cover or without cover, without the addition of chemical fertilizer or organic matter. This diversity in cultivation practices is explained by the means of production available to the producers and the fact that the crop is at an embryonic stage and is intended for family food and sometimes to supplement agricultural income. This

result is consistent with those obtained by Parthasarathy et al. and Nandkangre [17,16] who reported the same practices. These authors have shown that ginger is grown near lowlands or in shady places. It was clarified that ginger plants undergo photoinhibition when subjected to strong lighting and grow better when the lighting is less intense [18].

Agro-morphological variability

This study has identified three different groups of ginger in southern Benin from the different accessions collected. This classification is made on the basis of post-harvest data. These are qualitative and quantitative data taken from the rhizomes of the different accessions before planting. The rhizomes of the accessions showed variation in skin color. Mostly they are white in color. But some show a purple or red color. This is in agreement with Ravindran et al. [19] who mention a difference in skin color in some rhizomes. In addition, Nandkangre [16] observed the same structuring of accessions from the ginger germplasm collection from Burkina Faso. He indicated three (03) groups from the Ascending Hierarchical Classification (AHC) based mainly on characters such as yield, rhizome length, rhizome width and plant height. The same genetic structuring was obtained from the 47 ginger accessions using 15 Simple Sequence Repeat (SSR) markers in Burkina Faso [16]. In Nigeria, in addition to the yellowish-skinned ginger ("TaffinGiwa") which is the most prevalent, there are black morphotypes ("Yasun Bari") according to Ravindran et al. [19]. A variety of ginger with a red color ("var. rubra") has been described in Malaysia ([19].This clear distinction in rhizome skin color could be used as a varietal criterion in distinguishing ginger varieties. Accessions mostly have short-fingered rhizomes. The different types of rhizome fingers can be an important criterion in choosing ginger cultivars. A cross section of the rhizome shows the presence of fibers in the flesh. The major objectives in improving ginger are aimed at increasing yield, adaptability of varieties as well as reducing rhizome fibers [17]. The large differences between minima and maxima for characters such as length (4,400-12,900cm), width (1,4000-3,400cm) and thickness (1,400-3,400cm) of the rhizome, as well as the weight of the rhizome per plant (9.000-155.00 g) testify to the variation of these characters between the cultivars that make up this collection. The weight of the rhizome per plant (33.03 g) differs from that obtained by Jatoi et Watanabe [20] which is 108 g. Additionally, Sasikumar et al. [21] obtained a higher value (158 g). According to Nandkangre [16], the results of the surveys carried out showed that producers preferentially produce varieties of ginger with short fingers. They claim that these varieties have a much more pungent taste than those with long fingers. A cross section of the rhizome shows the presence of fibers in the flesh. The rhizomes which have an high fiber density represent 58.9% of the Burkina Faso collection. The same variabilities observed within the Burkina

Faso collection were obtained in the accessions used in this study. Ginger is one of the neglected crops in Benin and may be threatened by the loss of genetic diversity. The survival and evolution of species depends on the preservation of genetic diversity within populations [22]. Medicinal plants like ginger are under threat of loss of variability due to overexploitation [23]. Due to its mode of vegetative propagation, the genetic variability of ginger is limited [24].

CONCLUSION

This study has revealed the ethnobotanical knowledge associated with the use of ginger and to measure the level of genetic diversity at the morphological level of the species in southern Benin. The ethnobotanical results suggest that in southern Benin, ginger is known by various names for an aspect that is intrinsic to it and producers adopt several practices for its cultivation. A variation of local names is observed within socio-cultural groups. The different forms of use of the species vary according to ethnicity, gender and age. Relatively low genetic diversity was observed at the phenotypic level

Consent for publication

The respondents were informed that their opinions were to be published in a scientific paper and gave their approval.

consent

Prior to data collection, participants gave Written consent to participate in the study.

REFERENCES

1. MAEP. Plan Stratégique de Relance du Secteur Agricole (PSRSA), Version finale. Cotonou : Rapport; 2011.
2. Houngbo E. Dynamique de pauvreté et pratiques agricoles de conservation de l'environnement en milieu rural africain : le cas du plateau Adja au sud bénin. Thèse. Université d'Abomey-Calavi, Bénin. 2008; 328.
3. INSAE. Les entreprises agricoles au Bénin. Cotonou: INSAE; 2010.
4. PSDSA ; PNIASAN. Plan Stratégique de Développement du Secteur Agricole (PSDSA) 2025 et Plan National d'Investissements Agricoles et de Sécurité Alimentaire et Nutritionnelle PNIASAN 2017-2021. Cotonou: Rapport; 2017.

5. Singh G, Kapoor IPS, Singh P, Heluani CS, Lampasona MP, Catalan CAN. Chemistry, antioxidant and antimicrobial investigations on essential oil and oleoresins of *Zingiber officinale*. Food and Chemical Toxicology. 2008; 46: 3295–3302.
6. Singh M, Khan M, Moinuddina MA, Naeem M. Augmentation of nutraceuticals, productivity and quality of ginger (*Zingiber officinale* Rosc.) through triacontanol application. Plant Biosystems. 2012; 141(1): 106-113.
7. Nandkangre H, Ouedraogo M, Sawadogo M. Caractérisation du système de production du gingembre (*Zingiber officinale* Rosc.) au Burkina Faso : Potentialités, contraintes et perspectives. International Journal of Biological and Chemical Science. 2015; 9(2): 861-873.
8. Cragg GM, Newman DJ. Natural products: A continuing source of novel drug leads. Bioch Biophys Acta. 2013; 1830 (6): 3670-3695.
9. Deme K, Konate M, Ouedraogo HM, Sanou J, Sawadogo M. Importance, Genetic Diversity and Prospects for Varietal Improvement of Ginger (Zingiber officinale Roscoe) in Burkina Faso. World Journal of Agricultural Research. 2021 ; 9 (3) : 92-99.
10. Foine A. Les Zingiberacées en phytothérapie : l'exemple du gingembre. Thèse. Université de Lille 2, France. 2017; 185.
11. Médina F. Fiche technique de la poudre de gingembre. Thiès : Baobab des saveurs; 2011.
12. Thomson M, Al-Qattan KK, Al-Sawan SM, Alnaqeeb MA, Khan I, Ali M. The use of ginger (*Zingiber officinale* Rosc.) as a potential anti-inflammatory and antithrombotic agent. Prostaglandins, Leukotrienes and Essential Fatty Acids. 2002; 67 (6): 475-478.
13. Wail EA, Emad MA. Antibacterial Activity of Ginger (*Zingiber officinale* Rosc.) Rhizome: A Mini Review. International Journal of Pharmacogn Chinese Medecine. 2018; 2(4): 000142.
14. Dagneli P. Statistiques théoriques et appliquées. Bruxelles : De Boeck et Larcie; 1998.
15. Agbo IR, Missihoun AA, Vihotogbe R, Assogbadjo EA, Ahanhanzo C, Agbangla C. Impacts des usages traditionnels sur la vulnérabilité de *Detarium microcarpum* Guill et Perr. (Caesalpiniaceae) dans le district phytogéographique Zou au Bénin (en Afrique de l'Ouest).International Journal of Biological and Chemical Sciences. 2019 ; 11 (2) :734-735.
16. Nandkangre H. Caractérisation génétique et identification de variétés de gingembre (*zingiber officinale* Rosc.) adaptées au système de production au Burkina Faso. Thèse. Université ouaga 1 pr. joseph ki-zerbo, Burkina Faso. 2016;115.

17. Parthasarathy VA, Srinivasan V, Nair R.R, Zachariah TJ, Kumar A, Prasath D. Ginger: Botany and Horticulture. Indian Institute of Spices Research Indian Council of Agricultural Research. Kerala : PO Marikunnu Calicut; 2012.
18. Zhao W, Wang S, Huang XLH, Sui X, Zhan Z. Molecular cloning and characterization of the light-regulation and circadian-rhythm of the VDE gene promoter from *Zingiber officinale.* Plant Cell Rep. 2012; 31: 1381-1382.
19. Ravindran PN, Babu NK, Shiva KN. Botany and crop improvement. In: Ravindran PN, Babu NK, (eds). Medicinal and aromatic plants-Industrial profiles: Ginger, the genus *Zingiber*. Washington DC: CRC Press; 2005.
20. Jatoi SA, Watanabe KN. Diversity analysis and relationships among ginger landraces. Pak. J. Bot. 2013; 45(4): 1203-1214.
21. Sasikumar B, Babu KN, Abraham J, Ravindran PN. Variability, correlation and path analysis in ginger germplasm. Indian Journal of Genetic. 1992; 52(4): 428-431.
22. Barrett SCH, Kohn JR. Genetics and evolutionary consequences of small population size in plants: Implications for conservation. In: Falk DA, Holsinger KE, (eds). Genetics and conservation of rare plants. Oxford: University Press; 1991.
23. Kadambari S, Malik B. Invitro conservation of *Zingiber officinale* through rhizome. Journal of Pharmacy and Biological Sciences. 2014; 3 : 39-40.
24. Babu K.N, Suraby EJ, Cissin J, Minoo D, Pradeepkumar T, Parthasarathy VA, Peter KV. Status of transgenics in Indian spices. Journal of Tropical Agriculture. 2013; 51 (1-2): 1-14.