Diversity, Knowledge, and Use of Plants in Traditional Treatment of Diabetes in the Republic of Benin

Fernand Obafèmi Arnauld Laleye, Sylvanus Mensah, Achille Ephrem Assogbadjo, and Hyacinthe Ahissou

Research

Abstract

We assessed the diversity, knowledge, and use of antidiabetic plants by traditional healers, plant traders, and farmers from different locations in Benin. Altogether, 254 face-to-face interviews were conducted using a semi-structured questionnaire. Plant diversity was described, based on species richness. Jaccard Index was used to examine the similarity between locations. Consensus values for plant part and manner of use were also computed. A generalized linear model (GLM) with a Poisson distribution was applied to assess the effects of social factors on informants' knowledge. A total of 203 antidiabetic plant species were mentioned, belonging to 176 genera and 72 families. Predominant used plant parts were leaves, roots, and bark. Main methods of remedy preparations included decoction and infusion. The number of plants mentioned was significantly different among locations ($P < 0.05$; highest value being found in South Borgou), categories of age ($P < 0.05$; with adults and older people better informed than youngsters), and types of occupation ($P < 0.05$; healers reporting more species than farmers and traders). The variation in knowledge among healers, farmers, and traders depended on the location and the category of age. For instance, adult healers disclosed more plants than adult farmers and adult traders, but knowledge of plants was similar either when they were young or old. This study revealed that plants were frequently collected from crop fields and forests, raising concerns of sustainable harvest. It is suggested that home gardens be promoted as tools to reduce pressures on natural forests and prevent medicinal plant erosion.

Introduction

There is consensus that human health and well-being depend on many goods and services, much of which are medicinal plants. Approximately 65–80% of people in developing countries use traditional medicine for primary health care (Dold & Cocks 2002, WHO 2002). In the meantime, use of medicinal plants is promoted due to high levels of poverty limiting access to modern medicine. As a result, use of medicinal plants has gained relevance, even at the policy level, evidenced by the initiation of multiple institutes and programs for research on medicinal plant such as the Institute of Medicinal Plant Development (IMPLAD) in Beijing (China) and the Special Programme for Research and Training in Tropical Diseases (TDR) based in Geneva (Switzerland).

The growing population of diabetic patients (Boyle *et al.* 2001) and the higher costs and uncertainty related to the treatment of diabetes (Adegoke & Oloyede 2013) have

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increased the importance of issues that work towards discovering the novel therapeutic properties from plants. Consensuses have emerged that identifying the potential plants that can produce such antidiabetic properties must be primary to this goal (Bailey & Day 1989, Ghourri *et al.* 2013). Accordingly, studies have documented the diversity and use of antidiabetic plants by indigenous communities in Asia (Chhetri *et al.* 2005, Grover *et al.* 2002, Kadir *et al.* 2012, Ocvirk *et al.* 2013, Tag *et al.* 2012) and Africa societies (Gbolade 2009, Ghourri *et al.* 2013, Semenya *et al*. 2012a). From these studies, it appeared that people's knowledge about plant and medicinal potentials may vary, even at smaller scales. Therefore, it is believed that the assessment of the diversity of plants used in the traditional treatment of diabetes will still produce a good impact on the ethnobotany of antidiabetic plants.

Ethnobotanical studies, though extensively documented, still deserve some attention. First, it has been argued that the pattern of ethnobotanical knowledge, in relation to social factors, is more strongly associated with plant use categories, including medicinal plants. For example, in the gender-related knowledge about natural resources use, men were currently reported to have higher knowledge than women (Kristensen & Balslev 2003, Wekerle *et al.* 2006), although the trend is inverted when looking at medicinal plants (Begossi *et al.* 2002, Souto & Ticktin 2012). That is, according to the category of uses, the pattern of plant knowledge might vary among the social groups. On the second hand, most studies have come up with a positive association between age and traditional knowledge (Case *et al.* 2005, Kidane *et al.* 2014, Saynes-Vásquez *et al.* 2013), probably because knowledge tends to accumulate through life cycle (Beltrán-Rodríguez *et al.* 2014). But, it is worth understanding whether this trend varies according to the type of occupation. In other words, the extent to which a social factor can explain the variation in people's knowledge may depend on the level of another one (Souto & Ticktin 2012).

One additional point to make is about the change of the vegetation type and its composition as results of latitudinal gradient effects (Rosenzweig 1991), which may be a variable used to predict the availability of medicinal plant species and, therefore, the knowledge on these plants. Unfortunately, if the use of plants and the variation in knowledge within indigenous people are frequently related to the difference in social factors such as origin, gender, age, and occupation (Camou-Guerrero *et al.* 2008, Campos & Ehringhaus 2003, Case *et al.* 2005, Souto & Ticktin 2012), the application of geographical concepts is lagging (Beltrán-Rodríguez *et al.* 2014). For instance, occupation is a decisive social variable for effective knowledge (Camou-Guerrero *et al.* 2008); a herbalist is assumed to be more knowledgeable in the healing attributes of plants than a farmer. But the effects of occupation on people's knowledge may work at different rates according to the location and the available vegetation. Beltrán-Rodríguez *et al.* (2014) found that occupation was significantly associated with knowledge ($P < 0.05$), but suggested that other factors—such as density of useful species, floral heterogeneity, and altitudinal variations—should be accounted for in the variation in the ethnobotanical knowledge. Therein, we believed that the type of occupation could significantly explain the knowledge among informants depending on location, age, or gender.

In this paper, we applied a geographical analysis to assess the diversity, uses, and knowledge on antidiabetic plants. We explored different phytogeographical districts that spread over the three bioclimatic regions, from southern to northern Benin. The country is a prime study area in that traditional medicine is widespread and still the mainstay of primary health care of many people (Assogbadjo *et al.* 2010, Fandohan *et al.* 2010, Koura *et al.* 2011). However, very few studies have investigated the use of antidiabetic plants in Benin (Fah *et al.* 2013). The available information is on the antidiabetic plants sold by plant traders in two communal districts of southern Benin. Hence, other potential groups of informants such as traditional healers, diabetic patients, or agricultural farmers who can readily provide reliable details on potential antidiabetic plants were not considered (Bhattarai *et al.* 2006, Ocvirk *et al.* 2013, Semenya *et al.* 2012b).

This study, therefore, assessed the diversity, uses, and knowledge of the plants used in the traditional treatment of diabetes in the Republic of Benin. The following specific questions were addressed:

1) What is the diversity (richness) of plants used in diabetes management? How similar is the knowledge of antidiabetic plants between locations? Accordingly, we tested whether (i) closer locations or phytodistricts exhibit higher similarity in the plant species cited.
2) What are the most reported species and how consistent is their citation across the study area? We also determined whether (ii) a most reported species was highly and consistently mentioned in each location.
3) What are the plant parts and traditional preparation methods used?
4) Does the knowledge on antidiabetic plants depend on age, gender, occupation, or location? If so, how?

With these questions, we tested whether (iii) older people, women, and healers are the best informed and (iv) whether age and location have additional information value in understanding the variation in plant knowledge among healers, farmers, and plant traders.

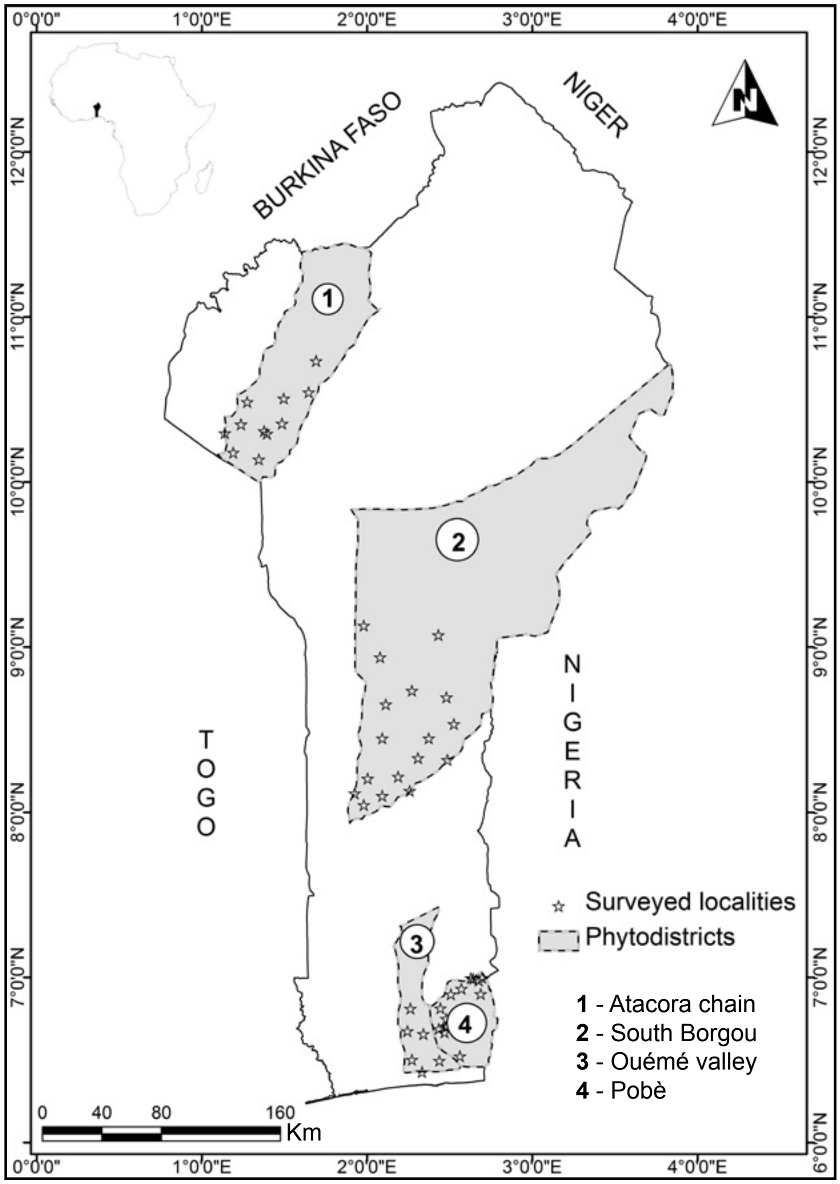

Figure 1. Location of the areas of study in Benin.

Materials and Methods

Study area

This study was carried out in four out of the ten phytogeographical districts (referred to as phytodistricts or locations) in the country (Adomou *et al*. 2006). These four phytodistricts were selected in a way to span the three bioclimatic zones of the country (Figure 1). These phytodistricts include Pobè and Ouémé valley (in the Guinean bioclimatic zone), South Borgou (in the Sudano-Guinean bioclimatic zone), and Atacora chain (in the Sudanian bioclimatic zone). The reason for the selection of different phytodistricts is attributable to their difference in terms of soil and vegetation conditions (Table 1). From the four phytodistricts, 56 villages were randomly selected to conduct the ethnobotanical survey.

Ethnobotanical surveys

Ethnobotanical surveys were conducted with three groups of informants: traditional healers, medicinal plant traders, and farmers. Altogether, 254 informants (122 traditional healers, 38 medicinal plant traders, and 94 farmers; Table 1) were identified and interviewed in the 56 selected villages. The small number of traders in our sampling was due to the fact that they were mobile, compared with the traditional healers and farmers. During this research, it

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Table 1. Ecological characteristics and informant demographics relative to the studied phytodistricts in Benin. Ratio female/male and informants' age range are in brackets.

Phytodistrict	Pobè	Ouémé valley	South Borgou	Atacora chain	Total
Climatic zones	Guinean		Sudano-Guinean	Sudanian	-
Location	6°25'–7°30'N		7°30'–9°45'N	9°45'–12°25'N	-
Main vegetation	Semi-deciduous forest	Swamp and semi-deciduous forest	Dry forest, woodland, and riparian forest	Riparian forest, dry forest, and woodland	-
Major soil type	Ferrallitic soils without concretions	Hydromorphic soils	Ferruginous soils on crystalline rocks	Poorly evolved and mineral soils	-
No. of villages	15	8	18	15	56
No. of informants	42 (10/32; 34–67)	83 (12/71; 25–82)	84 (26/58; 22–88)	45 (5/40; 35–79)	254 (53/201; 22–88)
Farmer	16 (0/16; 34–67)	26 (0/26; 25–82)	31 (18/13; 29–83)	21 (0/21; 35–75)	94 (18/76; 25–83)
Healer	15 (0/15; 35–65)	40 (3/37; 25–78)	47 (2/45; 22–88)	20 (2/18; 40–79)	122 (7/115; 22–88)
Trader	11 (10/1; 39–56)	17 (9/8; 25–73)	06 (6/0; 42–53)	04 (3/1; 42–70)	38 (28/10; 25–73)

was difficult to find many of the traders at their residence, as they usually move towards local and regional markets to sell their medicinal products.

Informants' permission was obtained, with help of local leaders. A semi-structured questionnaire was administered separately to each informant. Interviews were conducted at informants' residences. Socio-economic data (social attributes, gender, age, and level of education) of the informant was recorded. Interviewees were then asked about the plants used to treat diabetic patients. For each plant reported, interviewees were asked three specific questions: (i) What are the plant parts used? (ii) What are the manners of use? and (iii) Where is the plant collected from? Finally, interviewees were requested to show the specimen of each reported plant. Plant local names were checked using regional floras—*Flore du Bénin* (De Souza 1988) and *Flore Analytique du Bénin* (Akoègninou *et al.* 2006)—for identification. In the meantime, plant materials were collected, dried, and stored for final identification at the National Herbarium of the University of Abomey-Calavi (BENIN) in Cotonou, Benin.

Data analyses

Plant diversity and citation

We described the diversity in plant species, based on the species richness. The relative frequency of each family was calculated as the number of species (for a given family) divided by the total number of species for all families. Since one of our hypotheses was based on spatial variation of plant knowledge, we explored the similarity of plant knowledge among phytodistricts using Jaccard Similarity Index (JI; Höft *et al.* 1999). The index measures the degree of similarity between two localities using the number of species (c) shared by the two localities, the number of species present in locality A (a), and the number of species present in the locality B (b), as described below:

$$JI = c/(a+b+c)$$

The JI values range between 0 and 1, the maximal value expressing a complete similarity.

Frequency of citation was calculated to assess species relative utility as perceived by the interviewees. The frequency of citation was computed as the number of citations (for a given species) divided by the number of all citations for all species (Ocvirk *et al.* 2013). The most frequently reported species were identified, and a Principal Component Analysis (PCA) was performed on their relative frequency of citation to examine if the citation was consistent across phytodistricts.

Plant parts and manner of use

We assessed the use of plant parts by calculating the consensus value for plant part (Cpp) (Monteiro *et al*. 2006).

Cpp was computed as the number of citations for a given plant part divided by the total number of citations for all parts. It measures the extent of agreement among the informants concerning the plant part used.

The manner of use was assessed by calculating the consensus value for the manner of use (Cmu) (Byg & Baslev 2001). Cmu was computed as the number of citations for a given manner of usage divided by the total number of citations for all manners of use. It measures the extent of agreement among the informants concerning the manner of usage of plants. Both Cpp and Cmu were calculated for all the species weighed together and for each of the most frequently cited species.

Effects of demographic factors on informants' knowledge

Informants' knowledge was measured using their ability to mention a plant used to treat a diabetic patient. The number of plant species reported by a participant is seen as his/her contribution to the global knowledge pool on all plant species. Moreover, using the number of reported species enables a quantitative indication of how much knowledge, in terms of species, exists within informants (Camou-Guerrero *et al.* 2008). It is commonly used as a proxy to assess the degree of knowledge of plant resources (Beltrán-Rodríguez *et al.* 2014, Camou-Guerrero *et al.* 2008, Souto & Ticktin 2012).

The effects of gender, age, occupation, and location were assessed using Poisson Generalized Linear Model (in absence of over-dispersion), with the number of species as response variable. Both Analysis of Variance (ANOVA) and Kruskal-Wallis tests were further used, depending on the distribution of the data set, to test if the number of plants known differed among occupations within phytodistricts and categories of age, and vice-versa. Because there were very few women in some types of occupation

Table 2. Relative frequency (RF) of antidiabetic plants species in 72 families according to reports from respondents in four phytodistricts of Benin.

Family	RF (%)	Family	RF (%)	Family	RF (%)
Fabaceae	13.8	Myrtaceae	1.0	Commelinaceae	0.5
Apocynaceae	5.9	Polygalaceae	1.0	Convolvulaceae	0.5
Asteraceae	5.4	Portulacaceae	1.0	Dichapetalaceae	0.5
Euphorbiaceae	4.4	Sapindaceae	1.0	Gentianaceae	0.5
Malvaceae	4.4	Sapotaceae	1.0	Hypoxidaceae	0.5
Rubiaceae	4.4	Verbenaceae	1.0	Iridaceae	0.5
Poaceae	3.9	Zingiberaceae	1.0	Lauraceae	0.5
Combretaceae	3.4	Acanthaceae	0.5	Menispermaceae	0.5
Anacardiaceae	2.5	Araceae	0.5	Moringaceae	0.5
Meliaceae	2.5	Araliaceae	0.5	Musaceae	0.5
Phyllanthaceae	2.5	Aristolochiaceae	0.5	Ochnaceae	0.5
Amaryllidaceae	2.0	Asparagaceae	0.5	Olacaceae	0.5
Annonaceae	2.0	Bixaceae	0.5	Opiliaceae	0.5
Lamiaceae	2.0	Boraginaceae	0.5	Orobanchaceae	0.5
Moraceae	2.0	Brassicaceae	0.5	Papaveraceae	0.5
Arecaceae	1.5	Bromeliaceae	0.5	Passifloraceae	0.5
Bignoniaceae	1.5	Burseraceae	0.5	Pedaliaceae	0.5
Connaraceae	1.5	Cannabaceae	0.5	Piperaceae	0.5
Cucurbitaceae	1.5	Cannaceae	0.5	Plumbaginaceae	0.5
Rutaceae	1.5	Capparaceae	0.5	Polygonaceae	0.5
Solanaceae	1.5	Caricaceae	0.5	Thymelaeaceae	0.5
Amaranthaceae	1.0	Celastraceae	0.5	Xanthorrhoeaceae	0.5
Apiaceae	1.0	Chrysobalanaceae	0.5	Ximeniaceae	0.5
Dioscoreaceae	1.0	Clusiaceae	0.5	Zygophyllaceae	0.5

(18 vs. 76 for the farmers and 7 vs. 115 for the healers), the effect of gender (men vs. women) was tested regardless of occupation. All statistical tests were carried out in the R statistical software, version 2.15.3 (http://www.Rproject.org/). The generalised linear model (GLM) with a Poisson distribution was applied using "glm" function in the R software system.

Sites of collection of antidiabetic plants/plant parts

Information about harvest sites for plants/plant parts was analyzed in each phytodistrict using the consensus value for the collection site (Ccs). This index is defined as the number of citations for a given site divided by the total number of citations of all sites (Monteiro *et al.* 2006). It measures the extent of agreement among the informants concerning the collection site of the plant used.

Results

Taxa of medicinal plants

Informants reported a total of 203 medicinal plant species belonging to 176 genera and 72 families (Appendix 1). The most represented family was Fabaceae (28 spp.) followed by Apocynaceae (12 spp.), Asteraceae (11 spp.), and Euphorbiaceae, Malvaceae, and Rubiaceae (9 spp. each) (Table 2). Many families (70.8%) were relatively less represented (1–2 spp.).

Citation of species according to phytodistricts

Of the 203 reported plant species, 34, 63, 81, and 125 were cited in Pobè, Atacora chain, Ouémé valley, and South Borgou, respectively. The similarity index (Table 3) was relatively higher between geographically closer phytodistricts (Pobè and Ouémé valley, Ouémé valley and South Borgou, and South Borgou and Atacora chain), indicating that the closer phytodistricts shared more species and were more similar in antidiabetic plant knowledge.

The total number of citations varied according to the phytodistrict, as noticed for the number of species. The repartition of the number of species along with the number of citations showed that many plant species (158; 78%) were infrequently reported (<5 citations) compared with others: 26 plants (5–10 citations; 13%), 12 plants (10–15 citations; 6%), and 7 plants (>15 citations; 3%). The most frequently mentioned species (>15 citations) included *Citrus aurantiifolia* (Christm.) Swingle [34 citations], *Khaya senegalensis* (Desr.) A.Juss. [33 citations], *Momordica charantia* L. [32 citations], *Caesalpinia bonduc* (L.) Roxb. [18 citations], *Garcinia kola* Heckel [17 citations], *Catharanthus roseus* (L.) G.Don [16 citations], and *Moringa oleifera* Lam. [16 citations].

Table 3. Similarity in the plant knowledge between paired phytodistricts in Benin. Higher value of Jaccard Index indicates higher similarity.

Southern Benin →→→→→→→→→→ **Northern Benin**					
↓		Guinean		Sudano-Guinean	Sudanian
↓		6°25’–7°30’N		7°30’–9°45’N	9°45’–12°25’N
↓		Pobè	Ouémé valley	South Borgou	Atacora chain
↓	Pobè	-	0.12	0.11	0.09
	Ouémé valley	0.12	-	0.15	0.10
	South Borgou	0.11	0.15	-	0.13
Northern Benin	Atacora chain	0.09	0.10	0.13	-

Table 4. Principal component analysis describing the association between Benin phytodistricts based on most frequently cited antidiabetic plant species.

Species	**Axis 1 (40.69%)**	**Axis 2 (37.44%)**
Variance	1.627	1.498
Percentage of variance explained	40.685	37.443
Cumulative percentage of variance	40.685	78.128
Phytodistricts		
Pobè	0.993	-0.099
Ouémé valley	-0.009	0.554
South Borgou	0.677	0.685
Atacora chain	0.427	-0.844

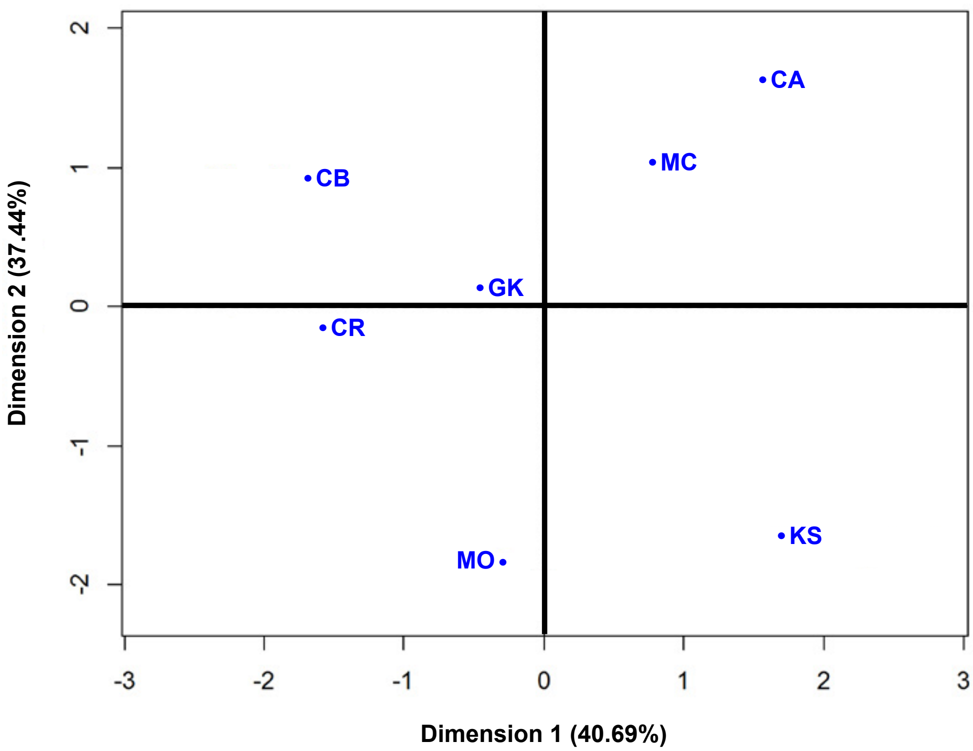
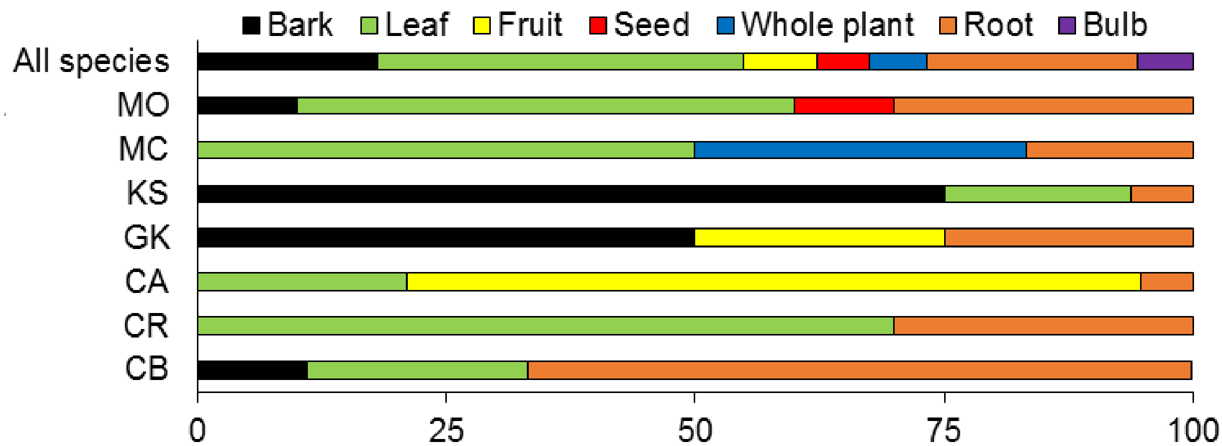


Figure 2. Principal component analysis showing the projection onto component axes of those antidiabetic plant species most frequently mentioned by survey participants from four phytodistricts in Benin. MO = *Moringa oleifera* Lam.; MC = *Momordica charantia* L.; KS = *Khaya senegalensis* (Desr.) A.Juss.; GK = *Garcinia kola* Heckel; CA = *Citrus aurantiifolia* (Christm.) Swingle; CR = *Catharanthus roseus* (L.) G.Don; CB = *Caesalpinia bonduc* (L.) Roxb.

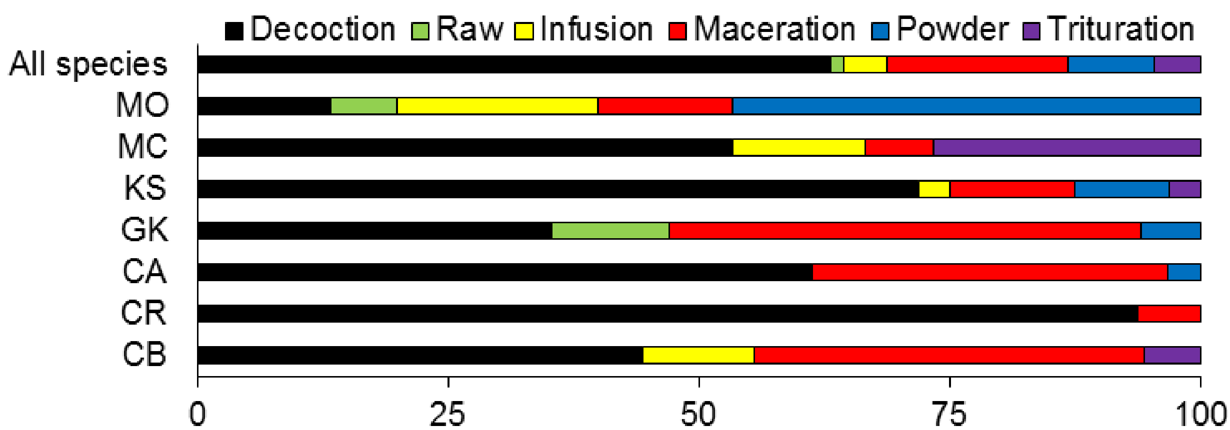
The first two principal axes, extracted from the PCA performed on the most reported species (Table 4), explained 78.1% of the total variance. The first axis (40.7%) was positively associated with Pobè and South Borgou (r = 0.99 and 0.68, respectively) while on the second axis (37.4%), South Borgou and Ouémé valley were positively correlated (r = 0.69 and 0.55, respectively) but opposed to Atacora chain (r = -0.84). The plot of the PCA, representing the two principal components (Figure 2) indicated that *K. senegalensis* and *C. aurantiifolia* were consistently highly reported in three phytodistricts, namely Pobè, South Borgou, and Atacora chain (for *K. senegalensis*) and Pobè, South Borgou and Ouémé valley (for *C. aurantiifolia*). *Momordica charantia* and *C. bonduc* were consistently highly mentioned in South Borgou and Ouémé valley. *Moringa oleifera* was mostly reported in Atacora chain. *Garcinia kola* and *C. roseus*, though being frequently reported, did not show any particular direction towards any phytodistrict.

Plant parts and manner of use

Bark, leaf, fruit, seed, root, and bulb were the plant parts reported as used (Figure 3). Use of the whole plant was also mentioned, especially for some herbaceous species. In general, the highest consensus value (36.8%) was recorded for leaves, followed by roots (21.3%) and bark (18%). The least reported plant part was bulbs. The differ-



A. Consensus value for plant part (%)



B. Consensus value for manner of use (%)

Figure 3. A. Plant parts used for each most frequently mentioned species. **B.** Manner of uses reported for each most frequently mentioned species. Species were reported as useful for treating diabetes by survey participants from four phytodistricts in Benin. MO = *Moringa oleifera* Lam.; MC = *Momordica charantia* L.; KS = *Khaya senegalensis* (Desr.) A.Juss.; GK = *Garcinia kola* Heckel; CA = *Citrus aurantiifolia* (Christm.) Swingle; CR = *Catharanthus roseus* (L.) G.Don; CB = *Caesalpinia bonduc* (L.) Roxb.

Table 5. Poisson regression model testing the effects of age, gender, location, and occupation on knowledge of anti-diabetic plants in Benin. Significant predictors are shaded.

Coefficients:	Estimate	Std. Error	z value	Prob (>|z|)
(Intercept)	-0.307	0.385	-0.796	0.426
Old	0.983	0.307	3.200	0.001**
Adult	0.918	0.233	3.940	<0.001***
Men	0.316	0.125	2.535	0.011*
Healer	1.080	0.347	3.112	0.002**
Trader	0.489	0.790	0.619	0.536
Ouémé valley	0.125	0.127	0.984	0.325
Pobè	0.181	0.141	1.280	0.200
South Borgou	0.698	0.118	5.900	<0.001***
Age × Healer	0.021	0.006	-3.862	<0.001***

ent manners of use were decoction, infusion, maceration, trituration, powder, and raw consumption, but the ones most frequently quoted were decoction and maceration (Figure 3). For the most reported species, the following were observed in terms of most reported plant part(s) and most reported manner(s) of use:

- *Moringa oleifera*: leaf and root; powder and infusion.
- *Momordica charantia*: leaf and root, but the whole plant was also frequently mentioned; decoction and trituration.
- *Khaya senegalensis*: bark; decoction.
- *Garcinia kola*: bark, followed by fruit and root; maceration and decoction.
- *Citrus aurantiifolia*: fruit; decoction and maceration.
- *Catharanthus roseus*: leaf; decoction.
- *Caesalpinia bonduc*: root; decoction and maceration.

Effects of gender, age, location, and occupation on knowledge of informants

Gender was a significant predictor of knowledge. The results of Poisson regression model (Table 5) indicated that men were significantly and positively related with the number of plants reported (β = 0.3; Z = 2.5; P = 0.011). They mentioned relatively higher number of plants than women (Figure 4).

The number of plants mentioned was significantly different among categories of age (P < 0.01) (Table 5). Adults (30–60 years old) and aged people (over 60 years) were associated with a significant increase in the number of plants cited (β = 0.9; Z = 3.9; P < 0.001 for adults; β = 1; Z = 3.2; P = 0.001 for old people), suggesting that they know more plants than youngsters (Figure 4).

The phytodistricts strongly influenced the ability of informant to mention an antidiabetic plant. The results of Poisson regression model indicated that informants from South Borgou were associated with a significant increase in the number of plants known (β = 0.7; Z = 5.9; P < 0.001). Accordingly, the highest mean number of plants mentioned was found in South Borgou (Figure 4).

Occupation also strongly influenced the number of plants mentioned by the informants. Traditional healers were significantly (P = 0.002) and positively associated with an increase in the number of plants cited (β = 1.1). They mentioned a higher number of plants, followed by the farmers and the traders who were less knowledgeable (Figure 4).

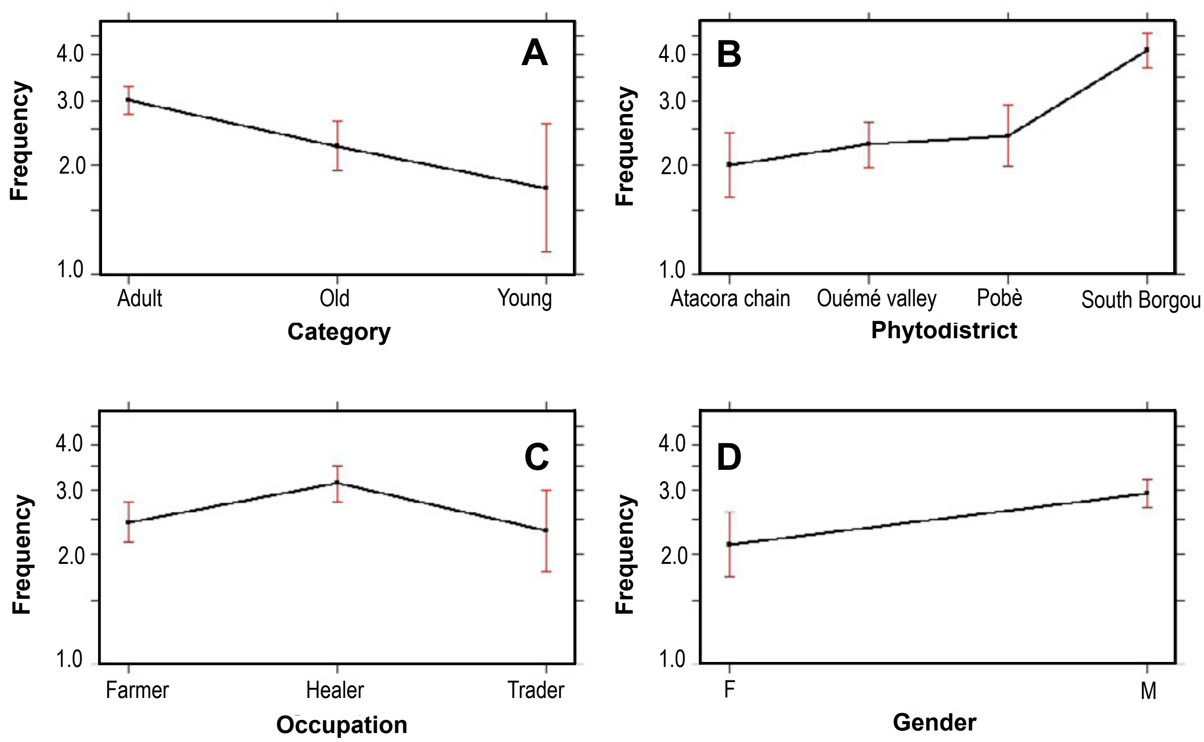


Figure 4. Mean number of reported species per informant relative to (**A**) age category, (**B**) phytodistrict, (**C**) occupation, and (**D**) gender. Species were reported as useful for treating diabetes by survey participants from four phytodistricts in Benin.

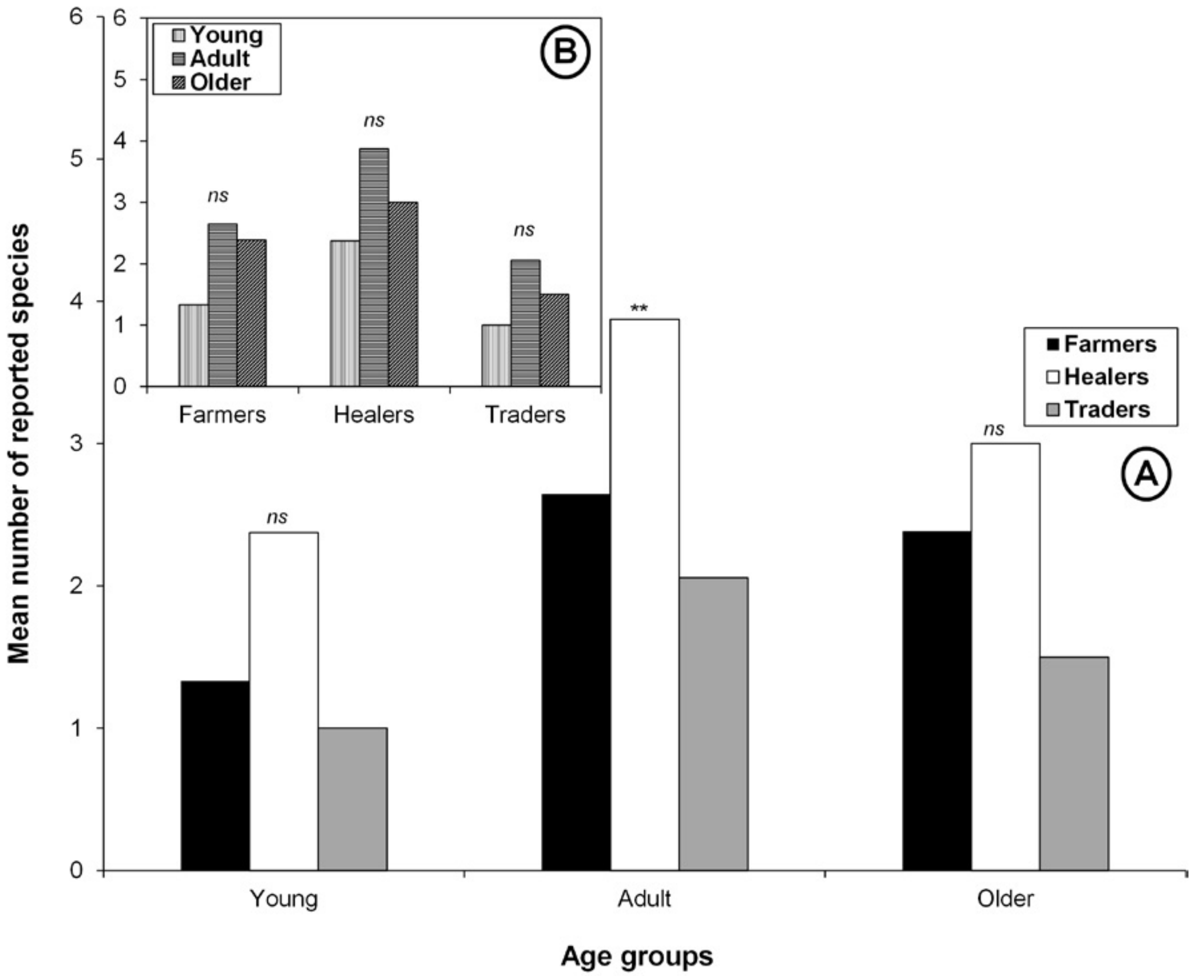


Figure 5. Mean number of reported species according to (**A**) occupation within age category and (**B**) category of age within occupation. Species were reported as useful for treating diabetes by survey participants from four phytodistricts in Benin; *ns*: not significant; *: significant at 0.05; **: significant at 0.01.

Interaction effects of age, location, and occupation on knowledge

The number of plants varied significantly according to the interaction between occupation and age ($P < 0.001$) (Table 5). The effect of occupation on knowledge of plants depended on the category of age. Adult healers were significantly more knowledgeable than adult farmers and traders (Kruskal-Wallis test, Chi-square = 12.22, $P = 0.002$), but the number of plants reported was the same either when they were young (ANOVA, $F = 2.38$, $P = 0.148$) or when they got old (Kruskal-Wallis test, Chi-square = 1.27, $P = 0.529$) (Figure 5A). The trend that we observed in the age-related knowledge of plants (i.e., adults and old people know more plants than youngsters) was also observed for each type of occupation (Figure 5B), but differences were not significant ($P > 0.05$).

There were also interaction effects between location and occupation. Indeed, the number of plants mentioned was significantly different among farmers, healers, and traders in South Borgou (Kruskal-Wallis test, Chi-square = 7.30, $P = 0.025$) while the difference was not significant in Pobè (Kruskal-Wallis test, Chi-square = 1.92, $P = 0.381$), Ouémé valley (Kruskal-Wallis test, Chi-square = 0.77, $P = 0.677$), or Atacora chain (Kruskal-Wallis test, Chi-square = 2.30, $P = 0.315$). This highlights a specific effect of location on occupation-related knowledge (Figure 6A). Differences were significant among phytodistricts, especially for the farmers (Kruskal-Wallis test, Chi-square = 9.40, $P = 0.024$) and the healers (Kruskal-Wallis test, Chi-square = 18.86, $P < 0.001$), while there was no significant phytodistrict effect on the ability of traders to mention a plant (Kruskal-Wallis test, Chi-square = 5.76, $P = 0.123$), showing that the effect of location varied with the type of occupation (Figure 6B).

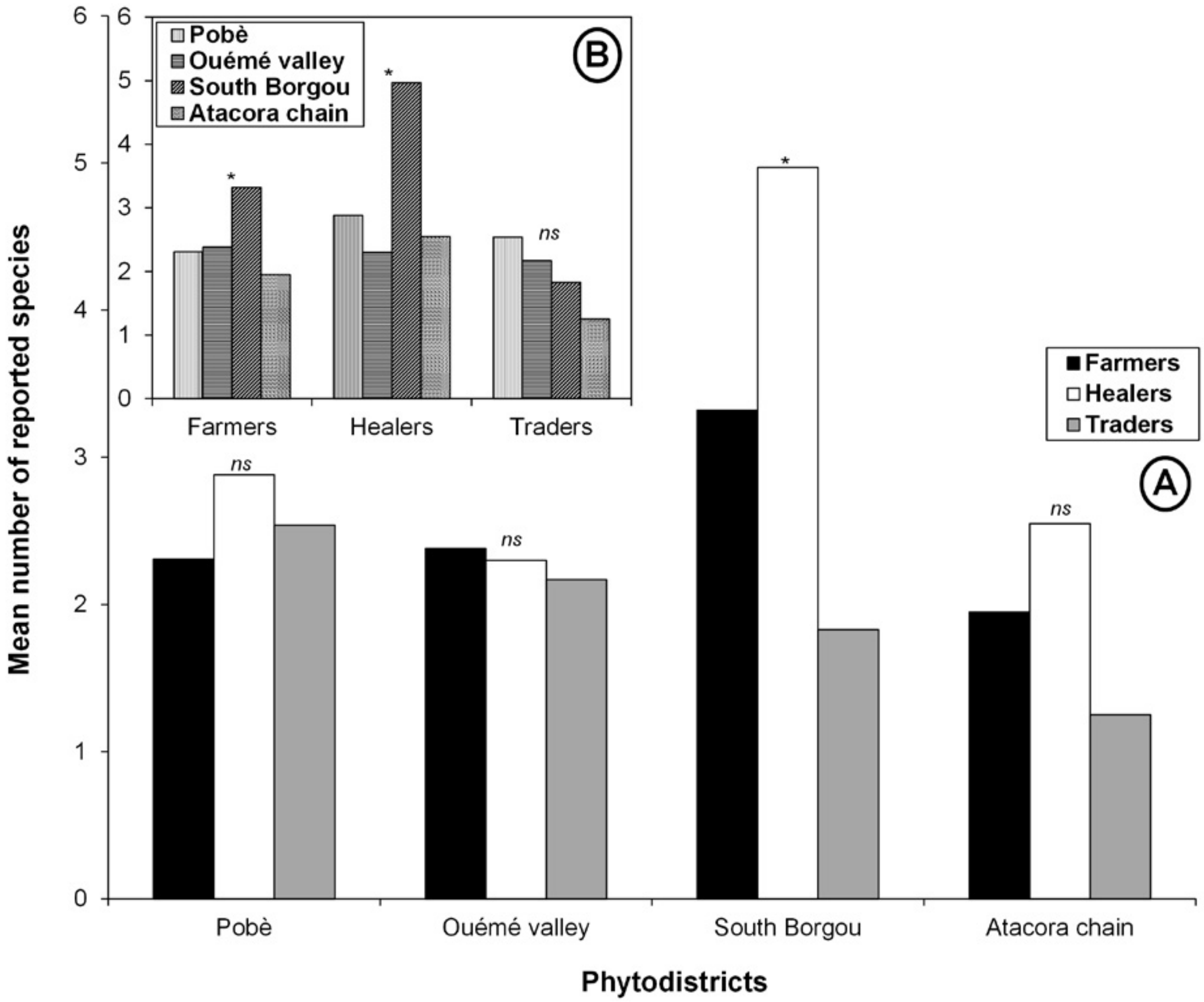


Figure 6. Mean number of reported species according to (**A**) occupation within phytodistrict and (**B**) phytodistrict within occupation. Species were reported as useful for treating diabetes by survey participants from four phytodistricts in Benin; *ns*: not significant; *: significant at 0.05; **: significant at 0.01.

Sites of collection of antidiabetic plants/plant parts

Plants/plant parts were reported as harvested from crop fields, fallows, and forests (Figure 7). They were additionally sometimes collected from home gardens. In Pobè, South Borgou, and Atacora chain, crop fields obtained the highest consensus values (38.1, 28.8, and 48.5% respectively), followed by forests (17.9, 25.7, and 25.7% respectively). In Ouémé valley, by contrast, plants were mostly retrieved from the forests (69.2%). Regardless of phytodistrict, the lowest consensus values for plant collection were observed for home gardens, indicating a weak availability of antidiabetic plants in the home gardens and also a weak attempt for *ex situ* conservation of the antidiabetic plants.

Discussion

Diversity of antidiabetic plants

Species of 72 different plant families were mentioned; most frequently these were members of Fabaceae, Apocynaceae, Asteraceae, and Euphorbiaceae, as also recently documented in others studies (Kadir *et al.* 2012, N'guessan *et al.* 2009). A study by Trojan-Rodrigues *et al.* (2012) on the plants used as antidiabetics in popular medicine in Rio Grande do Sul (southern Brazil), likewise, has highlighted a predominance of Asteraceae. Similar observations were also made by Semenya *et al.* (2012a) in South Africa. The wide distribution of these families may support our findings, but it is also possible that these dominant families comprise species that possess

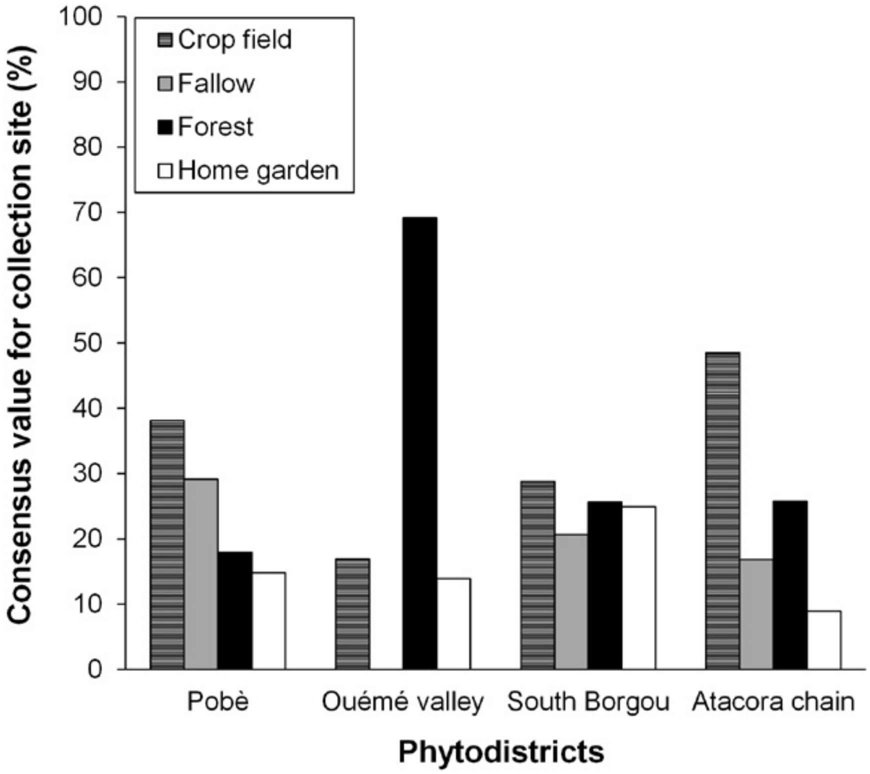


Figure 7. Collection sites of antidiabetic plants as reported by respondents from four phytodistricts in Benin.

many biologically active compounds which can be effective in the management of diseases. When compared with results from other studies, the number of plant species recorded in this study (203) is higher, e.g., compared to the 129 antidiabetic plants reported in the South of Maroc (Ghourri *et al.* 2013). This number is also remarkably higher than the one reported by Fah *et al.* (2013) in two different communal districts of Southern Benin (61 spp.). This difference may presumably be due to the spatial scale of the study. Indeed, we studied four phytodistricts covering the three bioclimatic zones of the country. These phytodistricts are different in terms of vegetation and soil condition (Adomou *et al.* 2006), which can make available different environmental conditions for more potential species. In line with this, the total number of reported species varied considerably according to the phytodistricts. However, the results also revealed that the geographically closer the phytodistricts, the more similar the informants' antidiabetic plant knowledge. Such a similarity between closer phytodistricts is indicative of the importance of geographical aspects to ethnobotanical knowledge.

Citation of antidiabetic plants

Many plant species were so poorly reported (1–2 citations) that their medicinal properties are questionable. We did not evaluate effectiveness of the reported species and, therefore, focused the discussion on the most frequently reported plants. Only few species were highly cited, and these are promising plants for phytochemical research and discovering new antidiabetic drugs (Hossan *et al.* 2010, Newman & Cragg 2007). An analysis of these most frequently mentioned species in each phytodistrict showed consistency in their high citation across different phytodistricts. This provides evidence that the antidiabetic potentialities of these plants are recognized among informants. Comparative analyses of the most reported species with some previous studies also revealed consistency. For example, *Citrus aurantiifolia* which scored the highest frequency of citation here (34) was also reported by Gbolade (2009) in Nigeria and Tag *et al.* (2012) in Bangladesh. Likewise, *Momordica charantia* has been reported in many studies throughout the world [Chhetri *et al.* (2005) in India, Gbolade (2009) in Nigeria, Semenya *et al*. (2012a) in South Africa, Kadir *et al.* (2012) and Ocvirk *et al*. (2013) in Bangladesh]. Similarly, the use of *Catharanthus roseus* (16 citations here) has been reported in other recent studies (Chhetri *et al.* 2005, Grover *et al.* 2002, Kadir *et al.* 2012). Studies have also reported the use of *Moringa oleifera*, as mentioned in our study (Semenya *et al*. 2012a, Tag *et al.* 2012). Some of the most frequently cited species (*M. charantia* and *M. oleif-*

era) were also highly reported by Bangladeshi traditional health practitioners (Kadir *et al.* 2012).

The results of this study showed other most frequently cited species—such as *Khaya senegalensis* (33 citations), *Caesalpinia bonduc* (18 citations), and *Garcinia kola* (17 citations)—revealing their high potential for the management of diabetes. Similarly, some species, such as *Phyllanthus amarus* Schumach. & Thonn., *Allium sativum* L., *Carica papaya* L., *Cocos nucifera* L., *Azadirachta indica* A.Juss., *Allium cepa* L., *Jatropha curcas* L., and *Mangifera indica* L. were also mentioned in previous studies (Grover *et al.* 2002, Kadir *et al.* 2012, Ocvirk *et al.* 2013) although they were moderately reported here (6–14 citations). More remarkably, species less reported in this study (one citation; e.g., *Abelmoschus esculentus* (L.) Moench*, Tamarindus indica* L., *Citrullus colocynthis* (L.) Schrad.) were found mostly enumerated elsewhere (Tag *et al.* 2012). This may likely be due to the abundance of these species in the study area but suggests that a lower frequency of citation for a species does not yet guarantee that this species is less important. One example is *Citrullus colocynthis* that has been found with potential antidiabetic effects (Benmehdi *et al.* 2011). Consequently, whenever a species is either most or least frequently mentioned, thorough investigation needs to be carried out on its efficacy and safety to help discover specific medicinal agents and properties. The traditional use of all these species to manage diabetes, combined with corroborating evidence from other studies, provide valuable contributions to the ethnobotanical records in Benin and elsewhere.

Plant parts and manner of use

When analyzing the use of plant parts, we found a frequent utilization of leaves, followed by roots and bark. Leaves were often revealed in many ethnobotanical studies to be the most preferred part of plant for the preparation of remedies, followed by root and bark. This is probably because leaves are easy to collect compared with roots, flowers, and fruits (Giday *et al.* 2009, Telefo *et al.* 2011). This observation may also be due to the fact that leaves are the main photosynthetic organs containing photosynthates, which might be responsible for active principles (Bhattarai *et al.* 2006). In this respect, many studies have reported the medicinal properties of extracts from leaves. This is also true with some plant species reported in this study from which leaf extracts have been tested elsewhere. This study showed, *inter alia*, that leaves were the most harvested plant parts from *M. charantia*, *M. oleifera,* and *C. roseus*. Leaf extracts from *M. charantia* have shown hypoglycemic effects on animal models (Chaturvedi 2012, Grover *et al.* 2002). Similarly, ethanolic extracts from leaves of *C. roseus* have helped control blood glucose and lipids in serum and tissues in alloxanized rats (Malviya *et al.* 2010).

Apart from leaves, use of roots and bark was also mentioned. In agreement with our results, some studies have reported the use of roots and bark for many antidiabetic plant species (Kadir *et al.* 2012, Tag *et al.* 2012). This indicates that these plant parts may possess antidiabetic agents. Fruits, seeds, bulbs, and even the entire plant were also of use. For instance, fruits were mostly harvested from *C. aurantiifolia*. This is in line with Jung *et al.* (2006) who reported that *C. aurantiifolia* fruit is a source of hesperidin and naringin, which are known for their antihyperglycemic effects.

Reported methods of remedy preparation were decoction, infusion, maceration, trituration, powder, and raw consumption. All these methods have consistently been documented in other studies (Albuquerque 2006, Dold & Cocks 2002, Semenya *et al.* 2012a). The use of a given processing method seems to be more dependent on the plant part than the practitioner. However, this requires further detailed research to have a comprehensive insight into the rationale behind the adequacy of a plant part to a manner of use.

Influence of gender, occupation, location, and age on knowledge of informants

The number of reported plant species was used to assess the degree of knowledge of antidiabetic plants. It is worth noting that using this variable as proxy to have an indication of how much knowledge exists within informants does not always yield information about the quality of the knowledge. Our findings revealed that informants' knowledge was related with gender, occupation, location, and category of age.

Gender-related knowledge

The difference in the mean number of reported plants observed between women and men indicates that an informant's gender is associated with ethnobotanical knowledge. From previous studies, differences in ethnobotanical knowledge between women and men showed controversy when looking at the specific categories of uses (Beltrán-Rodríguez *et al.* 2014, Camou-Guerrero *et al.* 2008, Souto & Ticktin 2012). Differences were found between men's and women's knowledge in relation to the plants they use at the interspecific and intracategorical levels. In this case, the fact that men cited more species than women may be due to the close association of men's knowledge with the treatment of diabetes.

Occupation-related knowledge

The results revealed that informants' knowledge varied according to occupation. In fact, the type of profession is relevant to characterize the structure of knowledge among people (Boster 1985). In general, traditional healers mentioned more species than farmers, followed by traders. This was not a surprise since traditional healers are always included in many ethno-medicinal studies for their potential knowledge of medicinal plants and recipes (Cheikhyoussef *et al.* 2011, Semenya *et al*. 2012b). They have acquired extensive knowledge of medicinal plant use (WHO 2002) and practice the art of healing through the use of plants, animals, and mineral substances with social, cultural, and religious background (Van Rensburg *et al.* 2002). On the contrary, farmers deal with land plowing and animal rearing and might not build their skills on medicinal use of plants. However, it was surprising that farmers reported more species than plant traders. Some studies have showed that primary activities (land plowing and animal rearing) contribute to use of natural resources and provide a particular contribution to ethnobotanical knowledge (Beltrán-Rodríguez *et al.* 2014, Saynes-Vásquez *et al.* 2013). Moreover, medicinal plants encompass both cultivated and wild plants. The curious result that medicinal plant traders reported relatively less species than farmers, especially in Atacora chain and South Borgou, is likely due to the low number of traders in our samples (4 and 6 in Atacora chain and South Borgou, respectively, vs. 20 and 47 for healers and 21 and 31 for farmers).

Age-related knowledge and interaction
between age and occupation

The results showed that adults and older people knew more species than younger people, probably because ethnobotanical knowledge is accumulated over time (Begossi *et al.* 2002, Beltrán-Rodríguez *et al.* 2014, Camou-Guerrero *et al.* 2008, Campos & Ehringhaus 2003). Indeed, knowledge acquisition is a process associated with time in that youngsters usually learn from elders. While many studies have illustrated a knowledge gap according to age categories, with exception of a few (e.g., see Byg & Balslev 2004), we additionally found a significant interaction between occupation and age. Indeed the trend in the effect of occupation on knowledge varied with the categories of age in that there was no gap in knowledge among healers, farmers, and traders either when they were young or when they got old. This is in line with Souto & Ticktin (2012) who have illustrated a similar knowledge among people when they are old. The similar knowledge among older traders, farmers, and healers reflects the effects of experience acquisition over time.

Location-related knowledge and interaction
between location and occupation

Influence of location on people's knowledge can be attributed by the abundance and degree of availability of plants (Campos & Ehringhaus 2003). In this study, the effect of location on informants' knowledge is reflected by the highest number of plants reported in South Borgou (in the Sudano-Guinean bioclimatic zone). This highest record is attributable to the fact that this bioclimatic zone is characterized by open vegetation of woodlands and dry forests that harbor many herbaceous and woody species (Mensah *et al*. 2014) and can offer considerable medicinal plants. This is in line with the study by Adomou *et al*. (2006) who found that the phytodistrict of South Borgou was revealed to be the richest in the total number of plant species (335 spp.) compared with Pobè (284 spp.), Ouémé valley (209 spp.), and Atacora chain (330 spp.). However, the equal mean number of medicinal plants reported in Pobè and Ouémé valley (in the Guinean zone) reflects the proximity of the two phytodistricts (Figure 1) and, therefore, a relatively similar ethnic diversity (mainly Yoruba, Fon, Weme, and Nago).

The lower number of plants mentioned in Atacora chain stresses the importance of ethnicity. In fact, a low ethnic diversity was captured by our sampling in Atacora chain, and informants were mainly Nateni and Waama. This low ethnic diversity may be responsible of the lower record of antidiabetic plants. On the contrary, informants in South Borgou were highly ethnically diversified (Idatcha, Mahi, Ditamari, Shabè, and Fulani). The high ethnic diversity in South Borgou may also explain the highest record of antidiabetic plants. In this line, some past studies have well documented the positive association of Idatcha, Mahi, and Fulani people (interviewed in South Borgou) with the use of plant species (Assogbadjo *et al*. 2010, Fandohan *et al*. 2010, Gaoué & Ticktin 2009, Koura *et al*. 2011).

The location-related trend that we observed in the knowledge of plants (i.e., informants from South Borgou cited more plants than other informants) was also observed within some types of occupation, namely healers and farmers, but not with the traders, indicating that the influence of location varied with the type of occupation. The similar number of species reported by the plant traders among locations may be explained by the nature of this occupation, which, in almost all the cases, extends beyond the local place of the traders. As traders can travel to sell the medicinal plants, it is possible that traders from different locations might meet and interact at some common places such as markets. These interactions may undoubtedly contribute to the similar knowledge on antidiabetic species among traders from different phytodistrict regions.

In almost all the phytodistricts, the healers reported a high number of species, followed by farmers and traders, but differences were significant only in the South Borgou phytodistrict, revealing that the effect of occupation on informants' knowledge was dependent on the location. The difference that we observed in the number of plants reported by healers, farmers, and traders especially in South Borgou, with the healers most knowledgeable, may be due to the preponderance of home gardens in that phytodistrict, compared with other phytodistricts (Figure 7), and a probable linkage between healing activity and owning garden.

Conservation of antidiabetic plant species

Conserving natural biological diversity has become a priority since the 1992 Rio de Janeiro Convention, and this was enhanced by the Millennium Ecosystem Assessment (MEA 2005). Here, we discuss the potential threats related with the use of these antidiabetic plants. This is guided by an examination of the harvested plant parts and the different habitats where plants and plant parts are harvested from.

Conserving natural biological diversity is relevant for the present study, as medicinal services are provided by plants with a risk of diversity erosion. Some species were highly cited (from 16 up to 34). The more cited, the more used and, therefore, the more vulnerable. Thus, they need to be considered in conservation strategies.

The results revealed that many plant parts (bark, leaf, fruit, seed, root, bulb, and whole plant) are used for diabetes treatment. The use of plant parts may make the species vulnerable unless they are harvested sustainably (Bhattarai *et al.* 2006). Indeed, the reported use of the whole plant and the roots may be prejudicial for plant stability or propagation (Cunningham 2001) compared with the use of aerial organs (e.g., leaves, fruits, and seeds) because these plant structures are renewable (Sheldon *et al.* 1997). However, Bhattarai *et al.* (2006) stressed the vulnerability of plants as a result of leaves harvested, and related this with the fact that they contain more chemical defense compounds in the form of biologically active metabolites. Similarly, it has been reported that the harvest of leaves and fruits might well affect the reproductive performance of the species (Gaoué 2008, Hall & Bawa 1993).

Many reported species are weeds (e.g., *M. charantia* and *C. roseus*) or cultivated (*M. oleifera* and *C. aurantiifolia*), as revealed by the consensus value for collection sites in each phytodistrict. Their harvesting may harm the individual plant, but they are so common that there is no problem with overharvesting. However, there is a great concern of sustainability, especially when looking at the rare forest or savannah plant species from which roots or bark are harvested. In this context, forests were the second potential sources of plant collection, and many forest species were reported (e.g., *Khaya senegalensis, Pterocarpus erinaceus* Poir*., Anogeissus leiocarpa* (DC.) Guill. & Perr., *Vitellaria paradoxa* C.F.Gaertn., *Caesalpinia bonduc*, *Anacardium occidentale* L., *Burkea africana* Hook.). *Khaya senegalensis,* for example, was mostly reported with the use of its bark and leaves. The harvest of bark and foliage from *K. senegalensis* has long been documented as a factor related to the dwindling reproductive performance of the species (Gaoué 2008). Similarly, populations of species such as *P. erinaceus*, *A. leiocarpa*, *V. paradoxa,* and *C. bonduc* were stressed to be threatened in Benin (Assogbadjo *et al.* 2009, Assogbadjo *et al.* 2010, Glèlè Kakaï *et al.* 2011).

The efforts for domesticating these antidiabetic plants are weak, as revealed by the lowest consensus values for home gardens. It is, therefore, important to consider conserving the utilized plant species and preventing erosion. In this respect, the establishment of home gardens may be an effective way to mitigate the harmful effects of human pressures, e.g., the degradation of many natural habitats, such as forest, savannas, and wetlands.

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Appendix 1. Medicinal plant species used to treat diabetes as mentioned by informants from four phytodistricts in Benin (Pobè, Ouémé valley, South Borgou, Atacora chain). Count is the total number of times a species was mentioned by informants.

Family	Scientific name	Voucher specimen	Count
Acanthaceae	*Hygrophila auriculata* Heine	6541, 6061, 3610, 7092, 417, 3319	2
Amaranthaceae	*Alternanthera pungens* Kunth	4985, 1640, D-168, 4646, 34c	3
Amaranthaceae	*Amaranthus spinosus* L.	163, 275, 12, 1353	1
Amaryllidaceae	*Allium ascalonicum* L.	-	5
Amaryllidaceae	*Allium cepa* L.	-	7
Amaryllidaceae	*Allium sativum* L.	-	12
Amaryllidaceae	*Crinum zeylanicum* (L.) L.	1428, 488, 4793, 4797, 4373, 7533, 7253, 7604, 7645, 7677	3
Anacardiaceae	*Anacardium occidentale* L.	288, 1756, 4273, 565	6
Anacardiaceae	*Lannea acida* A.Rich.	4610, 1388, 2617, 2375, 6568	3
Anacardiaceae	*Lannea barteri* (Oliv.) Engl.	6362, 1528, 2013, 1325, 7685	2
Anacardiaceae	*Mangifera indica* L.	4108	6
Anacardiaceae	*Spondias mombin* L.	1309, 2395, 823, 7705	1
Annonaceae	*Annona senegalensis* Pers.	1996	1
Annonaceae	*Monodora myristica* (Gaertn.) Dunal	104b, 3729	8
Annonaceae	*Uvaria chamae* P.Beauv.	107b, 4972, 2234, 1601, 913, 6330, 6307, 2043, 372	9
Annonaceae	*Xylopia aethiopica* (Dunal) A.Rich.	109a, 109b, 109c, 3256, 1015	12
Apiaceae	*Centella asiatica* (L.) Urb.	2479, 982, 5575, 6144, 6960, 4300, 4516	2
Apiaceae	*Daucus carota* L.	-	1
Apocynaceae	*Calotropis procera* (Aiton) W.T.Aiton	23337, 23625, 6539, 223, 591, 518	2
Apocynaceae	*Carissa spinarum* L.	1568, 7404, 11926, 718, 1275, 1995, 5356, 6858	1
Apocynaceae	*Catharanthus roseus* (L.) G.Don	6798, 722	16
Apocynaceae	*Holarrhena floribunda* T.Durand & Schinz	933, 23192, 122, 6854, 95D, 4876, 1769, 1818, 2400, 6574	1
Apocynaceae	*Mondia whitei* (Hook.f.) Skeels	1954, 3007, 1605, 803	2
Apocynaceae	*Omphalogonus calophyllus* Baill.	4987, 123, 5161, 1943, 1581	1

Family	Scientific name	Voucher specimen	Count
Apocynaceae	*Picralima nitida* (Stapf) T.Durand & H.Durand	6849, 3619, 3666	13
Apocynaceae	*Raphionacme brownii* Scott-Elliot	4917, 2727, 2713, 3375	1
Apocynaceae	*Rauvolfia vomitoria* Afzel.	336, 173, 6805, 1487, 23072, 23409, 1655, 4436, 23655	6
Apocynaceae	*Saba comorensis* (Bojer ex A.DC.) Pichon	23151, 1868, 32, 6899, 7065, 6914, 25207, 4640	1
Apocynaceae	*Secamone afzelii* (Roem. & Schult.) K.Schum.	837, 1043, 5221, 3208, 1595, 280	2
Apocynaceae	*Strophanthus hispidus* DC.	1885, 3680, 4421, 23656, 172, 2242, 23971	2
Araceae	*Anchomanes dalzielii* N.E.Br.	7252, 7611, 4672, 4765, 4388	6
Araliaceae	*Cussonia arborea* Hochst. ex A.Rich.	6368, 23531, 96/TR5/47, 23705, 24021, 344, 5069	2
Arecaceae	*Borassus aethiopum* Mart.	4158, 3546	1
Arecaceae	*Cocos nucifera* L.	3851	10
Arecaceae	*Elaeis guineensis* Jacq.	23338, 23469, 4190	2
Aristolochiaceae	*Aristolochia albida* Duch.	5091, 3392, 3082, 74, 5095	3
Asparagaceae	*Sansevieria liberica* Gérôme & Labroy	520, 3501, 7306	3
Asteraceae	*Acanthospermum hispidum* DC.	353f, 352b, 352d, D-227, 232a	3
Asteraceae	*Acmella uliginosa* (Sw.) Cass.	1780, 2776, 3009, 3427, D-907	3
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	1484, B14, 96, 1978, 375b,	1
Asteraceae	*Cyanthillium cinereum* (L.) H.Rob.	-	1
Asteraceae	*Echinops longifolius* A.Rich.	536, 96/499, 96/604, 3077, D-933, 368a	1
Asteraceae	*Eclipta prostrata* (L.) L.	253, 366, 369g, 2281, 1344, 348,2501, D-318, 589, 689	1
Asteraceae	*Lactuca sativa* L.	7732	1
Asteraceae	*Launaea taraxacifolia* (Willd.) Amin ex C.Jeffrey	D-1141, 351, 64, 362, 22809, D-311, 47, 652	1
Asteraceae	*Tridax procumbens* L.	395a, D-73, D-243, 818, 59, 157, 571	1
Asteraceae	*Vernonia amygdalina* Delile	434, 352, D-162, 273, 293	10
Asteraceae	*Vernonia colorata* (Willd.) Drake	398c, 65, 395, 23022, 438, 398b, D-499, 398a	3
Bignoniaceae	*Kigelia africana* (Lam.) Benth.	194a, 194c, 194d, 3178, 6475	1

Family	Scientific name	Voucher specimen	Count
Bignoniaceae	*Newbouldia laevis* (P.Beauv.) Seem.	196e, 3087, 1963, 4203, 1296, 6842	4
Bignoniaceae	*Stereospermum kunthianum* Cham.	198a, 198b, 198c, 198g, 6559, 4543	2
Bixaceae	*Cochlospermum tinctorium* A.Rich.	D-875, 6981, 2082, 7774	1
Boraginaceae	*Heliotropium indicum* L.	206c, 713, 2710, 2587, 259, 7711	3
Brassicaceae	*Brassica oleracea* L.	3275, 7594, 7732	2
Bromeliaceae	*Ananas comosus* (L.) Merr.	3906	4
Burseraceae	*Commiphora africana* (A.Rich.) Engl.	23609, 4284, 3160, 2082	1
Cannabaceae	*Cannabis sativa* L.	1861a, 8347	3
Cannaceae	*Canna indica* L.	152, 1789	1
Capparaceae	*Crateva adansonii* DC.	1559, 861, 6535, 4315, 4153	14
Caricaceae	*Carica papaya* L.	2578, 4789, 102, 3722, 2578	11
Celastraceae	*Gymnosporia senegalensis* (Lam.) Loes.	3195, 2038, 4500, 4548, 6156, 1431, 7699, 2464, 1698	1
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	2473, 6649, 487, D-947, 4553, 1145	3
Clusiaceae	*Garcinia kola* Heckel	4182, 3089, 1773	17
Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	785, 894, 96/640, 1053	3
Combretaceae	*Combretum collinum* Fresen.	6649, 2192, 23561, 24280, 752, 2008, D-789, 8068, 1146, 6156	1
Combretaceae	*Combretum micranthum* G.Don	2417, 24109, 24290, 670, 8217, 1226, 264	5
Combretaceae	*Pteleopsis suberosa* Engl. & Diels	1423, 701, 96/601, D-581, 7000	2
Combretaceae	*Terminalia catappa* L.	370, 339a	4
Combretaceae	*Terminalia glaucescens* Planch. ex Benth.	808, 3045, D 529, 575, 3423	2
Combretaceae	*Terminalia mantaly* H.Perrier	780	1
Commelinaceae	*Commelina erecta* L.	0346, 11, 907, 1599, 1570, 96/524, 13, 7438, 2522	1
Connaraceae	*Cnestis ferruginea* DC.	3051, 22907, 1730, 300, 405, 11890, 11166, 1299	4
Connaraceae	*Connarus africanus* Lam.	70, 196, 2880, 3097, 4946	1
Connaraceae	*Rourea coccinea* (Schumach. & Thonn.) Benth.	4446, 22798b, 1529, 6259, 5321, 6151	1

Family	Scientific name	Voucher specimen	Count
Convolvulaceae	*Merremia quinquefolia* (L.) Hallier f.	2912, 97, 247, D-442, D-450, 3393	1
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	446a, 4875, 1531, 6393	1
Cucurbitaceae	*Momordica balsamina* L.	3715	1
Cucurbitaceae	*Momordica charantia* L.	1052, 1676, 3845	32
Dichapetalaceae	*Dichapetalum madagascariense* Poir.	1535, 1797, 95, 4429, 2338, 4496	4
Dioscoreaceae	*Dioscorea cayennensis* Lam.	197, 3498, 235,3717	1
Dioscoreaceae	*Tacca leontopetaloides* (L.) Kuntze	2823, 2892, 87, 23538, 1826, 24270, 8115	2
Euphorbiaceae	*Croton gratissimus* Burch.	567a, 567c, 3495, 2039, 1560	5
Euphorbiaceae	*Croton zambesicus* Müll. Arg.	567a, 567c, 3495, 2039, 1560	3
Euphorbiaceae	*Euphorbia hirta* L.	575b, 2321, 3818, 1110, 2129	7
Euphorbiaceae	*Euphorbia hyssopifolia* L.	601g, 5258, 5862, 4197, D-71, 1356	1
Euphorbiaceae	*Euphorbia kamerunica* Pax	3821, 3361	1
Euphorbiaceae	*Euphorbia poissonii* Pax	1713, 3138	1
Euphorbiaceae	*Jatropha curcas* L.	4795, 3374, 3404	6
Euphorbiaceae	*Jatropha gossypiifolia* L.	1279, 1576, 3301, 795	2
Euphorbiaceae	*Manihot esculenta* Crantz	591a, 591c, 7569	3
Fabaceae	*Abrus precatorius* L.	6592, 23358, 637, 1423g, 1423d, 145, 1761, 3794, 3998, 1792	1
Fabaceae	*Acacia sieberiana* DC.	1438, 2021, 2599, 6934, 6534, 8188	1
Fabaceae	*Arachis hypogaea* L.	3842, 5295, 1595, 5210	1
Fabaceae	*Bauhinia rufescens* Lam.	221, 1629	1
Fabaceae	*Bobgunnia madagascariensis* (Desv.) J.H. Kirkbr. & Wiersema	23948, 2028, 713, 728, 7663, 7272, 2803, 1748, 3516	1
Fabaceae	*Burkea africana* Hook.	1856, 1630b, 2020, 4649, 23577, 7017, 1744, 7562, 686	3
Fabaceae	*Caesalpinia bonduc* (L.) Roxb.	2070, 4202, 5302, 1671	18
Fabaceae	*Caesalpinia pulcherrima* (L.) Sw.	2092, 97, 351, 1329, 6795	1
Fabaceae	*Cassia sieberiana* DC	408, B119, 512, 2343, 1227, 1412, 1022, 88/123, 237, 2092, 2299	1

Family	Scientific name	Voucher specimen	Count
Fabaceae	*Crotalaria retusa* L.	1344, 343, 58, 814, 53, 1712, 6035	1
Fabaceae	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	1429, 266e, 4025, 1236, 629	5
Fabaceae	*Detarium microcarpum* Guill. & Perr.	1272, 6537, 7288, 1843, 1662, 6162, 5006, 2865, 2188, 1816, 268a, 2340	2
Fabaceae	*Erythrina senegalensis* DC.	22855, 1919b, 568, 1919c, 6668, 23000, 758, 1816	2
Fabaceae	*Indigofera tinctoria* L.	535, 8405, 4544, 4397, 7629, 4397, 2806	1
Fabaceae	*Isoberlinia doka* Craib & Stapf	1273, 6037, 2063, 1277, 2910	1
Fabaceae	*Mimosa quadrivalvis var. leptocarpa* (DC.) Barneby	22692, D-82, 624, 6813, 415, 2327	1
Fabaceae	*Parkia biglobosa* (Jacq.) R.Br. ex G.Don	950f, 454, 1229, 2017, 4198, 6204	3
Fabaceae	*Phaseolus vulgaris* L.	-	1
Fabaceae	*Philenoptera cyanescens* (Schumach. & Thonn.) Roberty	3650, 23135, 2036, 1762, 485, 76, 1567, 1228, 5378	1
Fabaceae	*Piliostigma thonningii* (Schumach.) Milne-Redh.	1844, 799, 279a, 279g, 634, 1835, 1723, 320	2
Fabaceae	*Pterocarpus erinaceus* Poir.	472, 263, D-534, 1690, 2130	4
Fabaceae	*Rhynchosia pycnostachya* (DC.) Meikle	3956, 1400, 7409	1
Fabaceae	*Senna occidentalis* (L.) Link	195, 246, 174, 828, 812, 033, 232	3
Fabaceae	*Senna siamea* (Lam.) H.S.Irwin & Barneby	7801, 22710, 205, 2037, B110	6
Fabaceae	*Tamarindus indica* L.	7639, 1715, 1876, 1899, 1906, 5208, 282b, 7215, 2382	1
Fabaceae	*Tephrosia vogelii* Hook.f.	1788, 6721	1
Fabaceae	*Vigna unguiculata* (L.) Walp.	857, 7286	3
Fabaceae	*Zornia glochidiata* Rchb. ex DC.	2000, 810, 756, 2134, 483, 214, 2907, 7848, 6912	5
Gentianaceae	*Anthocleista vogelii* Planch.	412, 952, 3893	2
Hypoxidaceae	*Curculigo pilosa* (Schumach. & Thonn.) Engl.	2884, 1460, 2127, 2467, 1280	2
Iridaceae	*Gladiolus dalenii* van Geel	20, 125, 1622, 2718, 6915, 2728, 2293, 2027	1
Lamiaceae	*Hyptis pectinata* (L.) Poit.	22983	1
Lamiaceae	*Hyptis suaveolens* (L.) Poit.	6796, 2195, 1922, 5412, 4912	1

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Family	Scientific name	Voucher specimen	Count
Lamiaceae	*Ocimum americanum* L.	23622, 24124	5
Lamiaceae	*Ocimum gratissimum* L.	23627, 2763	6
Lauraceae	*Persea americana* Mill.	78	6
Malvaceae	*Abelmoschus esculentus* (L.) Moench	-	1
Malvaceae	*Adansonia digitata* L.	187a, 187b, 187c, 2269	1
Malvaceae	*Ceiba pentandra* (L.) Gaertn.	188a, 2547, 1710	1
Malvaceae	*Cola acuminata* (P.Beauv.) Schott & Endl.	3025, 1876c, 1876a, 22872	8
Malvaceae	*Cola millenii* K.Schum.	6824, 3278, 4164, 813, 1422d, 6289, 4399, 34D, 61	1
Malvaceae	*Cola nitida* (Vent.) Schott & Endl.	4183, 3121, 4611, 1664, 2175, 1132	1
Malvaceae	*Corchorus olitorius* L.	1137a, 1899c, 1899d, 1899, 2284	5
Malvaceae	*Gossypium arboreum* L.	1451a, 1451b, 853	1
Malvaceae	*Sterculia setigera* Delile	1428, 1459, 2036, 2371, 6494, 2621	1
Meliaceae	*Azadirachta indica* A.Juss.	139, 166, 180	9
Meliaceae	*Khaya senegalensis* (Desr.) A.Juss.	1480, 2436	33
Meliaceae	*Pseudocedrela kotschyi* (Schweinf.) Harms	751, 1271, 834, 2611, 469, 1422	1
Meliaceae	*Trichilia emetica* Vahl	1299, 2060, 1799, 7320, 2014	3
Meliaceae	*Trichilia prieuriana* A.Juss.	913d, 6640, 18, 6647, 90, 913c, 6153	2
Menispermaceae	*Triclisia subcordata* Oliv.	923b, 923e, 1474, 31, 2273, 2260, 3827	1
Moraceae	*Antiaris toxicaria* Lesch.	1547, B163, 216	1
Moraceae	*Ficus exasperata* Vahl	22806, 2203, 1260, 2064, 2247	3
Moraceae	*Ficus platyphylla* Delile	1923, 7318, 5183	1
Moraceae	*Milicia excelsa* (Welw.) C.C.Berg	23169, 277, 1476, 24236	1
Moringaceae	*Moringa oleifera* Lam.	4794, 1452b, 7740, 1761	16
Musaceae	*Musa × paradisiaca* L.	-	4
Myrtaceae	*Myrcianthes fragrans* (Sw.) McVaugh	-	5
Myrtaceae	*Psidium guajava* L.	216, 999a, 999b, 3526, 3200	7

Family	Scientific name	Voucher specimen	Count
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	7084, 7816, 518, 1016a, 3587, 1016h	2
Olacaceae	*Olax subscorpioidea* Oliv.	6282, 2149, 2200, 1316, 22951, 7652	1
Opiliaceae	*Opilia amentacea* Roxb.	1399, 1477, 1992, 1542, 7263, 7379, D-743, D-1011, 2612	1
Orobanchaceae	*Striga hermonthica* (Delile) Benth.	1156c, 1156, 6734, 2795, 83, 2556, 262, 2471, D-843	3
Papaveraceae	*Argemone mexicana* L.	7393, 1817, 4204	3
Passifloraceae	*Passiflora foetida* L.	751, 6785, 7365, 1364, 1051, 6500	2
Pedaliaceae	*Sesamum radiatum* Schumach.	561, 181, 272, 433, 1916, 330, 1942, 2196, 7041	1
Phyllanthaceae	*Bridelia ferruginea* Benth.	556h, 6309, 825, 725, 307, 6526	10
Phyllanthaceae	*Flueggea virosa* (Roxb. ex Willd.) Royle	607b, 4360, 1049, 1469, 1795, 6311	7
Phyllanthaceae	*Hymenocardia acida* Tul.	582a, 1957, 695, 7011, 815, 99	1
Phyllanthaceae	*Phyllanthus amarus* Schumach. & Thonn.	596b, 5550, 184, 3323, 928, 1740	14
Phyllanthaceae	*Phyllanthus pentandrus* Schumach. & Thonn.	601a, 102, 1328, 1528, 883, 7327	1
Piperaceae	*Piper guineense* Schumach. & Thonn.	1122	6
Plumbaginaceae	*Plumbago zeylanica* L.	3821, 6744	2
Poaceae	*Cymbopogon citratus* (DC.) Stapf	686a, 4785, 3485	1
Poaceae	*Cymbopogon giganteus* Chiov.	687a, 678d, 3645, 3105, 5325, 5212	1
Poaceae	*Imperata cylindrica* (L.) P.Beauv.	715a, 715b, 1278, 3545, 5825, 3541	4
Poaceae	*Oxytenanthera abyssinica* (A.Rich.) Munro	2208, 23983	2
Poaceae	*Pennisetum glaucum* (L.) R.Br.	743a, 5155, 2378	1
Poaceae	*Saccharum officinarum* L.	4154	1
Poaceae	*Sorghum bicolor* (L.) Moench	1561a, 2480, 7531, 4195, 6431	2
Poaceae	*Zea mays* L.	1474	1
Polygalaceae	*Carpolobia lutea* G.Don	6144, 1481, 1387, 1118, 6617	2
Polygalaceae	*Securidaca longipedunculata* Fresen.	6160, 1372, 196, 1974	2

Family	Scientific name	Voucher specimen	Count
Polygonaceae	*Persicaria senegalensis* (Meisn.) Soják	3855, 3345, 1002, 3770, 2024, 3409, 7294, 1649	4
Portulacaceae	*Portulaca grandiflora* Hook.	3271, 908, 3162, 7632	1
Portulacaceae	*Portulaca quadrifida* L.	1875a, 1875b, 8335, 7052, 2425, 2708	1
Rubiaceae	*Chassalia kolly* (Schumach. & Thonn.) Hepper	1342, 6358, 6730, 206A, 943, 728, 1678	3
Rubiaceae	*Gardenia aqualla* Stapf & Hutch.	2911, 2982, 2749, 658, D-673, 1154	3
Rubiaceae	*Gardenia ternifolia* Schumach. & Thonn.	6371, 2189, 1708, 2404	2
Rubiaceae	*Mitracarpus hirtus* (L.) DC.	2011, 195, D-22, 32, 179, 6419	2
Rubiaceae	*Morinda lucida* Benth.	1343, 1152, D-285a, 6651	10
Rubiaceae	*Nauclea diderrichii* (De Wild.) Merr.	1368	2
Rubiaceae	*Sarcocephalus latifolius* (Sm.) Bruce	6479, 3580, 2463, 3159, 7263	11
Rubiaceae	*Pavetta crassipes* K.Schum.	1408, 3438, 1742, 2329, 2026	2
Rubiaceae	*Vangueriella spinosa* (Schumach. & Thonn.) Verdc.	1478, 2753, 4452, 32	1
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	4023, 5026,6232	34
Rutaceae	*Clausena anisata* (Willd.) Hook.f. ex Benth.	1390, 3873, 4159, 1546, 5158, 114, 1910c, 6152	1
Rutaceae	*Zanthoxylum zanthoxyloides* (Lam.) Zepern & Timler	8402, 974a, 1599, 835, 7406, 4500, 2396	3
Sapindaceae	*Blighia sapida* K.D.Koenig	1882g, 5472, 1931d, 872, 1538	2
Sapindaceae	*Paullinia pinnata* L.	1695a, 30, 753, 2006, 6316, 8140	1
Sapotaceae	*Synsepalum dulcificum* (Schumach. & Thonn.) Daniell	70, 3363, 5490	1
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	459, 475, 1253, 1806, 4560, 7540	3
Solanaceae	*Capsicum annuum* L.	7814	5
Solanaceae	*Nicotiana tabacum* L.	3059, 2026a, 23511, 2883	1
Solanaceae	*Solanum erianthum* D.Don	6312, 1115, 1888, 830, 1555, 2900, 2379, 3673, 1042	1
Thymelaeaceae	*Gnidia kraussiana* Meisn.	1655, 4503, 2639, 1483, 2406, 4309, 1866b, 1417, 6095	1
Verbenaceae	*Lantana camara* L.	4160, 6799, 2542, 4579, 1755	2
Verbenaceae	*Lippia multiflora* Moldenke	1287, 478, 1336	1

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Xanthorrhoeaceae	*Aloe buettneri* A.Berger	24217, 1908, 2816, 1569, 7793, 6983, 2988, 1776, 2140, 2131, 5137	3
Ximeniaceae	*Ximenia americana* L.	750, 1987, 2656, 2095, 1845, 2447	2
Zingiberaceae	*Aframomum melegueta* (Roscoe) K.Schum.	23418	12
Zingiberaceae	*Zingiber officinale* Roscoe	-	2
Zygophyllaceae	*Balanites aegyptiacus* (L.) Delile	24230, 6433, 4537, 2575, 5180	1

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