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RESEARCH ARTICLE

Diversity, distribution and ethnobotanical importance of cultivated and wild African trifoliate yam [*Dioscorea dumetorum* (Kunth) Pax] in Benin

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Abstract *Dioscorea dumetorum* is an important native tuber crop commonly grown in West Africa. The present study aimed to document the indigenous knowledge related to its diversity and distribution as well its ethnobotanical importance in the production areas in Benin. In total, 555 farmers belonging to 18 socio-linguistic groups were surveyed in 78 villages covering the major production areas in the country. The study revealed that local farmers have developed important knowledge on the production and uses of this tuber crop. Twenty-five farmer-named landraces, further grouped into 3 major morphotypes, were globally recorded. Their extent and distribution varied significantly, with in general the southern and central agro-ecologies holding the largest cultivar diversity while the northern agro-ecologies being less diversified. The pure yellow cultivars were the most popular morphotype. The seed management system remained traditional. Farmers' preference criteria in selecting cultivars relied essentially on plant attributes and environment stress adaptations. The crop is grown mainly for food and trading purposes while it is also used in traditional medicine and magico-mystic rituals. Along with agro-ecological parameter, the results revealed that the socio-cultural factors such as the ethnic group and the age of farmers had significant impact the overall use value of *D. dumetorum*. Wild morphotypes of *D. dumetorum* were recognized and also exploited in ethnomedicine by farmers. Although well appreciated by the farmers, the potential of the crop was less exploited. Concerted efforts are needed to preserve and valorize its genetic resources to combat food insecurity and malnutrition in Benin.

Keywords Benin · *Dioscorea dumetorum* · Indigenous knowledge · Trifoliate yam · Varietal diversity · Wild morphotypes

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Introduction

Yam (*Dioscorea spp.*) is one of the most important edible tuber crops grown worldwide in tropical areas (Adoukonou-Sagbadja et al. 2014; Srivastava et al. 2012). It is a well appreciated crop with high economic and socio-cultural values in Sub-Saharan Africa where the crop significally contributes to the subsistence and incomes of several millions people (Jova et al. 2005). With about

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96% of global production (FAOSTAT 2013), the so-called 'yam belt' of West Africa is the principal area of yam production (Hahn et al. 1987). Monocot of the family of Dioscoreaceae, yam is a polyploid species with vegetative propagation. It belongs to the highly diversified genus *Dioscorea* that includes 644 species (Coursey 1967) among which only six have economic importance in West-Africa (Adeigbe et al. 2015). In this region, four of these six species are cultivated: *Dioscorea cayenensis* Lam., *D. rotundata* Poir., *D. alata* L. and *D. dumetorum* (Kunth) Pax (Mignouna and Dansi 2003). Except *D. alata*, the three other cultivated species are known to be native to West-Africa (Bhattacharjee et al. 2011). Besides, in contrast to the complex *D. cayenensis-D. rotundata*, the most cultivated and consumed yam in Africa, *D. dumetorum* is known to be less important in production but well appreciated by local populations (Adoukonou-Sagbadja 2001).

Commonly known as African bitter yam or cluster yam (Palaniswami and Peter 2008), *D. dumetorum* is a trifoliate or three-leaved yam found in the wild throughout tropical Africa between 158°N and 158°S and is cultivated in West and Central African countries (Dansi et al. 1999, Adaramola et al. 2016, Oladeji et al. 2016). It is reported to be the most nutritious of the commonly consumed yams (Afoakwa and Sefa-Dedeh 2002). The species is rich in vitamins and minerals with its tuber protein content (9.43–10.3%) more balanced than those in other cultivated yams such as *D. alata* (8.2%) and *D. rotundata* (7.6%) (Afoakwa and Sefa-Dedeh 2002). Moreover, *D. dumetorum* is regarded as an energy rich food with an easy digestible starch (Ukpabi 2015). According to Ferede et al. (2010), the deep yellow flesh of *D. dumetorum* contains Provitamin A and carotenoids comparable with those in yellow maize lines selected for increased concentration of provitamin A. Therefore, the species is considered as a good source of phyto-proteins, carbohydrate, vitamins and minerals for human nutrition (Degras 1993; Alozie et al. 2009). It is also reported that *D. dumetorum* possesses allelopathic, genotoxic and cytotoxic potentials that could possibly be further exploited for the development of anti-tumoral compounds or natural herbicides for weeds and other unwanted plants (Usman et al. 2014).

Despites its high economic value and effective potential in food and nutrition security supply, *D. dumetorum* remains a secondary crop in most producing countries in West-Africa compared to the complex *D. cayennensis-D. rotundata*. According to many authors, *D. dumetorum* is one of the numerous tropical underutilized and neglected yam species (Owuamanam et al. 2013; Medoua et al. 2005; Alozie et al. 2009; Akinoso and Abiodun 2013; Akinoso et al. 2016; Egbuonu et al. 2014) and therefore less investigated by agricultural or scientific research agencies. Nowadays, the recurrent food supply problem in developing countries has highlithed the necessity of promoting alternative food sources available such as those from neglected and underutilized plants (Adoukonou-Sagbadja et al. 2007).

In Benin, *D. dumetorum* is cultivated in southern and centre parts as well in the northern part of the country. In these producing areas, diverses landraces and wild forms were traditionally exploited by local communities. While it is well appreciated, no particular attention is devoted to the valorization and utilization of this yam crop species. Indeed, omitted some general studies on yam that mentions *D. dumetorum*, no diagnostic study has been carried out on this crop to know its diversity, its distribution and traditional management, conservation status, technical itinerary and production constraints, etc. Besides, no breeding efforts have yet been specifically accomplished on *D. dumetorum* in the country (Dansi et al. 2012). In such situations where documented data are hardly available, local farmers are the first source of information to initiate diversity studies (Tamiru et al. 2008). Farmers' knowledge and perceptions on crop landraces are important as these are only the unit of diversity they recognize but also the unit they manage and conserve (Tamiru et al. 2008).

The major objective of this study was therefore to contribute to the knowledge and better valorization of *D. dumetorum* in Benin. Specifically, the present study aims to (1) assess the varietal diversity of *D. dumetorum* used by farmers, its folk taxonomy and geographical distribution in the production areas in Benin Republic, (2) analyse farmers'preference criteria in selecting *D. dumetorum* cultivars for cultivation and use in the growing areas, (3) infer the traditional seed system management by local farmers in the producing areas, (4) document the ethnobotanical importance in terms of traditional uses and the impacts of the use values on the varietal diversity of the crop in the production areas of Benin, and finally (5) document farmers' knowledge in use and management of wild related forms of *D. dumetorum*. To achieve these

goals, several ethnobotanical surveys were conducted through the cultivation areas in Benin. The important information gathered from this study can help defining conservation strategies and facilitating breeding relevant cultivars that meet the farmers' needs.

Materials and methods

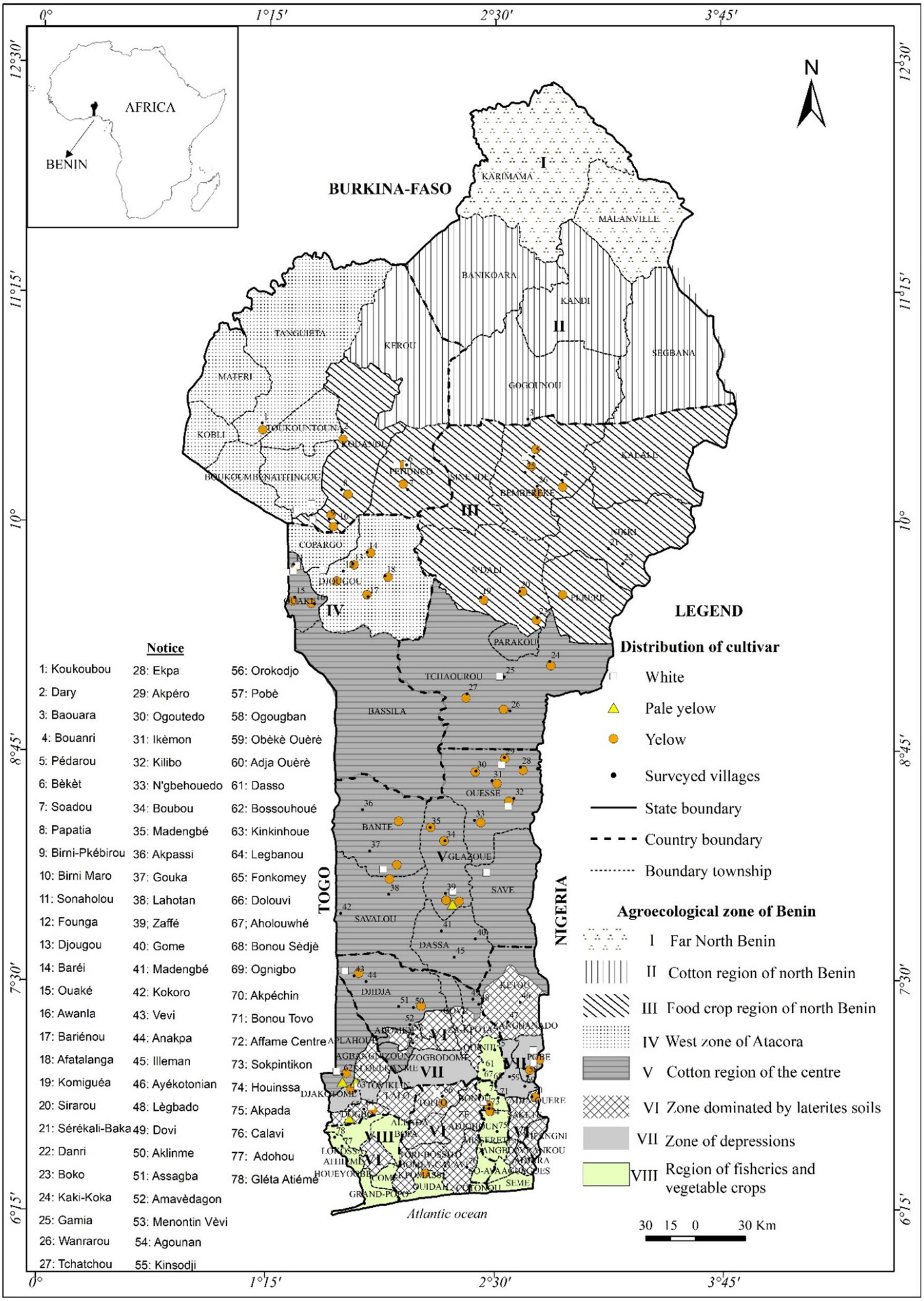
Description of the study area and selection of the surveyed sites

The study was conducted in the tribal areas of production of *D. dumetorum* in Benin Republic (Fig. 1). The country is located on West African Atlantic coast between the latitudes 6°10N and 12°25N and longitudes 0°45E and 3°55E. It includes several agroecologies characterized by climate and soils types differencies (Adomou 2011). The South and the Centre regions display a relatively humid climate with two rainy seasons and a mean annual rainfall varying from 1100 to 1400 mm (Yabi and Afouda 2012). The northern region is situated in arid and semi-arid agroecological zones characterized by unpredictable and irregular rainfalls oscillating between 800 and 950 mm/year with only one rainy season. Mean annual temperatures range from 26 to 28 °C and may exceptionally reach 35–40 °C in the far northern localities. The different types of vegetation encountered are semi-deciduous forest (south), woodland and savannah woodland (centre-east and northeast), dry semi deciduous forest (centre-west and south of northwest) and tree and shrub savannahs (far north).

Seventy-eight (78) villages (see list on Fig. 1) belonging to 6 agro-ecological zones (III, IV, V, VI, VII, VIII) and covering diverse sociolinguistic groups areas where *D. dumetorum* was found in cultivation around the country were randomly selected after an exploratory survey in agricultural research centers, rural and urban markets, and agricultural extension services (ex CARDER) through unformal discussions with diverse actors such as resources persons, farmers and sellers.

Ethnobotanical surveys and data collection

Diverse formal ethnobotanical surveys were conducted 2 years along (2015, 2016) in the different selected villages. In each village, traditional chiefs and local authorities were involved in the study to facilitate the meetings and data collection. *D. dumetorum* farmers were selected using snow ball method (N'Danikou et al. 2015). In this sampling approach, structured and semi-structured interviews based on questionnaire were conducted through the application of Participatory Research Appraisal tools and techniques such as individual and focus group discussions, matrix scoring and pairwise ranking and field visits using a questionnaire as recommended by Adoukonou-Sagbadja et al. (2006) and recently applied by Assogba et al. (2015) and Zavinon et al. (2018). The questionnaire used during the interviews was first pretested on a small sample of farmers and latter adjusted. During the surveys, the questionnaire was administered and the interviews were conducted with the help of translators recruited in each sociolinguistic group surveyed. A total of 555 producers were finally interviewed during the study. Through the discussions, the key information documented was related to sociocultural characteristics of farmers and their traditional knowledge on *D. dumetorum* cultivation and uses in the study area. The sociocultural information collected on *D. dumetorum* farmers concerned their age, sex and the ethnic groups they belonged to. Considering their traditional knowledge, farmers were first asked to inventory all the *D. dumetorum* cultivars they were managing and to describe their key distinctive agro-morphological attributes. In the present context, a cultivar designed the varietal diversity that farmers can clearly distinguish on the basis of agro-morphological traits, phenological attributes, postharvest characteristics and differential adaptive performances under local biotic and abiotic stress conditions (Adoukonou-Sagbadja et al. 2006; Zavinon et al. 2018). It includes as well landraces and improved varieties. Correspondences between cultivar names given in diverse languages were made to avoid bias in the inventory and to adequately define the different cultivar category following their described characteristics and the signification of their local name (Adoukonou-Sagbadja et al. 2006; Dansi et al. 2010). Other traditional knowledge documented was that related to farmers' preference and criteria in cultivar selection, planting seed systems and modes of management, the wild related forms exploited by farmers and their importance, etc. At needs, additional trips were specifically organized through the study



0°
1°15′
2°30′
3°45′
12°30′
11°15′
10°
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AFRICA
BENIN
N
BURKINA-FASO
TOGO
NIGERIA
Atlantic ocean
I
II
III
IV
V
VI
VII
VIII
Notice
1: Koukoubou
2: Dary
3: Baouara
4: Bouanri
5: Pédarou
6: Bèkèt
7: Soadou
8: Papatia
9: Birni-Pkébirou
10: Birni Maro
11: Sonaholou
12: Founga
13: Djougou
14: Baréi
15: Ouaké
16: Awanla
17: Bariénou
18: Afatalanga
19: Komiguéa
20: Sirarou
21: Sérékali-Baka
22: Danri
23: Boko
24: Kaki-Koka
25: Gamia
26: Wanrarou
27: Tchatchou
28: Ekpa
29: Akpéro
30: Ogoutedo
31: Ikèmon
32: Kilibo
33: N'gbehouedo
34: Boubou
35: Madengbé
36: Akpassi
37: Gouka
38: Lahotan
39; Zaffé
40: Gome
41: Madengbé
42: Kokoro
43: Vevi
44: Anakpa
45: Illeman
46: Ayékotonian
48: Lègbado
49: Dovi
50: Aklinme
51: Assagba
52: Amavèdagon
53: Menontin Vèvi
54: Agounan
55: Kinsodji
56: Orokodjo
57: Pobè
58: Ogougban
59: Obèkè Ouèrè
60: Adja Ouèrè
61: Dasso
62: Bossouhoué
63: Kinkinhoue
64: Legbanou
65: Fonkomey
66: Dolouvi
67; Aholouwhé
68: Bonou Sèdjè
69: Ognigbo
70: Akpéchin
71: Bonou Tovo
72: Affame Centre
73: Sokpintikon
74: Houinssa
75: Akpada
76: Calavi
77: Adohou
78: Gléta Atiémé
LEGEND
Distribution of cultivar
White
Pale yelow
Yelow
Surveyed villages
State boundary
Country boundary
Boundary township
Agroecological zone of Benin
I Far North Benin
II Cotton region of north Benin
III Food crop region of north Benin
IV West zone of Atacora
V Cotton region of the centre
VI Zone dominated by laterites soils
VII Zone of depressions
VIII Region of fisheries and vegetable crops
30 15 0 30 Km

◀**Fig. 1** Study area showing the agro-ecological zones, the diverse localities surveyed and geographical distribution of major traditional cultivated morphotypes of *D. dumetorum* in Benin. (Color figure online)

area during the year 2017 in order to complete the missing information from the latter surveys.

Data analysis

Globally, data were analyzed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (zone, villages, individuals, etc.) levels. To assess the landraces diversity of *D. dumetorum* and their importance in the study area, the quotation frequency of the landraces recorded during the surveys was used and the proportion of interviewees that quoted a given cultivar with regard to the total number of people surveyed was computed. For a better ranking, four quotation levels were considered to assess the relative importance of each *D. dumetorum* cultivar per agro-ecological zone: 1×: Quoted by 1–10% interviewees; 2×: Quoted by 10–20% interviewees; 3×: Quoted by 30–60% interviewees and 4×: Quoted by ≥ 70% interviewees. Besides, the spatial distribution of the varietal diversity was assessed at agro-ecological level in order to compare the variation within them. The importance of *D. dumetorum* cultivars among agro-ecological zones was assessed via the average area of farm allocated to each category of *D. dumetorum* cultivars. We performed a Kruskal–Wallis test on the area medians to compare the amount of area allocated to each category of *D. dumetorum* cultivar among agro-ecological zones.

Farmers' preferences and selection criteria used in the choice of *D. dumetorum* cultivars were recorded and a simple correspondence analysis was performed to identify the specificity of each agro-ecological zone with regard to the criteria used by farmers. Farmers' preference criteria used to select cultivars within each agro-ecological zone were also analyzed using multivariate analysis approaches. Indeed, a principal component analysis (PCA) was performed to understand the relationships between farmers' preference criteria and agro-ecological zones. Therefore the average score of each criterion was calculated and a data matrix (agro-ecological zones and criteria) was constructed to perform the PCA.

The different use categories of *D. dumetorum* in the agro-ecological zones were recorded with the socio-demographic characteristics of interviewees. The medicinal and magico-mystic importance of diseases/disorders treated by *D. dumetorum* was assessed by the mean of histogram of absolute quotation frequency. To determine the social factors responsible of the production, use and preservation of *D. dumetorum* in local communities, the effect of the agro-ecology, age, sex, and socio-linguistic membership (ethnic group) of farmers on overall reported use value of *D. dumetorum* was assessed through covariance analysis following Zavinon et al. (2018). The significant factors were retained for further analyses. Thus, the importance of the use category across the agro-ecological zones was assessed with principal component analysis. The same analysis was performed to assess the importance of *D. dumetorum* use among sociolinguistic groups surveyed as well the use pattern of *D. dumetorum* following the age and sex of interviewees.

Finally, the importance of wild related forms or wild morphotypes (WM) of *D. dumetorum* was assessed via quotation frequency in the agro-ecological zones. The morphologic characteristics of WM of *D. dumetorum* were recorded and simple correspondence analysis was performed to characterize them. All analyses were carried out with the R software package vs. 3.3.2 (R Development Core Team 2016).

Results

Socio-demographic characteristics of *D. dumetorum* farmers

In total, 555 producers have been interviewed during the study. They belonged to eighteen (18) ethnic groups among which traditionally 6 living the south, 3 the centre and 9 the north of the country. Among these 555 farmers, 84% of respondents were male while 16% were female with in average 16 years of experience in *D. dumetorum* production. Besides, 12% of the farmers surveyed were young people, 66% were adults (40–50 years) and 22% (under 50 years) were old people. In general, it apprears that the majority of producers in the study area were adults and old farmers

(88%) while the young people were less involved in *D. dumetorum* cultivation.

Varietal diversity and folk taxonomy in *D. dumetorum* in Benin

Through the study area, farmers have in general a good knowledge of cultivated *D. dumetorum* that is reported under diverse generic names according to the ethnic groups surveyed. In total, 25 different farmer-named cultivars were recorded during this study. Among these 25 cultivars, only one (*Agriki*) was recognized by farmers as an improved variety, but no information was available about the date of introduction, the year and structure of released. All other cultivars were landraces. The Table 1 summarises the generic and specific names of *D. dumetorum* varieties as well farmers' criteria in categorizing and naming cultivars through the ethnic groups surveyed in Benin.

In the study area, farmers recognized, identified, classified or described *D. dumetorum* cultivars using diverse phenotypic characteristics (root density on the tuber, color of the flesh, shape and cluster of tubers) or their provenance (origin). Each socio-lingustic group had its own series of vernacular names. For instance, *Holli* and *Nago* people used almost all these identified criteria in the vernacular naming system, i.e. provenance of the cultivar, root density on the tuber, tuber shape and flesh color. While, *Wémè* and *Idaasha* farmers used mainly the provenance and tuber shape in naming landraces. In reference to the flesh color, the most widely used criteria, farmers globally distinguished three landraces' categories: the pure yellow, the pale yellow and the white cultivars. The *Lokpa*, *Yom*, *Ditamari* used the flesh color and the clustered aspect of the tubers to name local varieties while *Bariba* people combined flesh color with tuber shape in naming cultivars. The *Agoun, Fon* and *Cotafon* distinguished cultivars based only on the flesh color.

Root density and tuber shape were also recorded as important farmers' criteria in naming landraces. For example, *Nago* and *Holli* farmers named landraces with dense roots on tubers as *Olichan igba* which means «tuber with thousand roots» , those developing few roots on tubers as *Olichan meta* (literacy tuber with three roots) and the cultivars having tubers without or with very few and sparse roots (smoot tubers) as *Konichan*. Besides, based on the tuber shape, *Gbôta* in *Adja* socio-linguistic group means "head of the sheep" and *Olomou Sobolo* in *Nago* socio-linguistic group means "breast shape". The Fig. 2 illustrates these features.

Some farmers also named their landraces by referring to the provenance history (origin). It was the case in *Wémè* tribal area where farmers distinguished *Goun léfé* (local or indigenous landrace) and *Ayô léfé* (from *Ayô*, former *Yorouba* kingdom in actual Nigeria). In this category, the cultivar *Agriki* was reported by *Holly and Nago* to be introduced by National Agricultural Research Services.

Socio-lingustic groups *Natemba*, *Wama*, *Biali* and *Sola* of the northwestern Benin, having less deep knowledge on this yam species, didn't use denomination criteria to distinghish cultivars. They only called *D. dumetorum* by its generic names such as *Tsémou Noka*, *Bokiwinta*, *Tayinbia* or *Bogwèna* (Table 1).

Globally, by combining correspondence analysis between names of cultivars with their major charactristics traits described by farmers, the 25 inventoried cultivars could be broadly classified into three main morphotypes: White, Pale-yellow and Pure-yellow (Fig. 3, Table 2). The white morphotype contains cultivars with tubers of irregular form developing dense roots all over their surface and many tiny rootlets on all their surface, white and rugourous tuber skin and white flesh color. The pale-yellow morphotypes developed rounded tubers, sparse roots and tiny rootlets on the half superior surface of the tubers, smooth tuber skin, and pale-yellow flesh color. Finally, the pure yellow morphotype includes cultivars that may develop oblong or rounded tubers with very rare roots only at the head of the tubers and total absence of rootlets on the surface, smooth gray tuber skin and pure-yellow flesh. All the three morphotypes would develop identical aerial vegetative (shoot, leaves) and reproductive (inflorescence, flowers) traits and could not be distinghuised on this basis.

Spatial distribution of varietal diversity of *D. dumetorum* in Benin

The number of cultivars inventoried varied from agro-ecological zone to another (Table 3). The agro-ecological zones VI, V and VII detained the highest diversity with respectively 12, 11 and 10 cultivars inventoried. The agro-ecological zones III, IV and VIII were less diversified with 6, 5 and 6 cultivars, respectively. Globally, the southern Benin displayed

Table 1 Generic names of *D. dumetorum,* specific names of cultivars and farmers' criteria in naming and classifying cultivars in diverse ethnic groups of Benin

Ethnic group	Local name and denomination criteria										Generic name
	Provenance (Source)	Tuber shape	Roots density on tuber			Flesh color			Tubers' cluster		
			Sparse	Medium	Dense	Pure yellow	Pale-yellow	White	Separate tubers	Fused tubers at the neck	
Adja	Sakété (from Sakété)	Gbôta (shaped of head of sheep)	***	***	***	Migoagban	Lébétou	***	***	***	Léfé
Agoun, Cotafon, Fon, Mahi	***	***	***	***	***	Vovo	***	Wéwé	***	***	
Wémè	Ayò léfé (from tribal country Ayò), Goun léfé (local)	***	***	***	***	***	***	***	***	***	
Holli, Nago	Agriki (from NARS)	Olomou Sobolo (shaped of breast)	Konichan	Olichan méta	Olichanigba	Kpoukpa	***	Foufou	***	***	Essou or Essrou
Idaasha	***		***	***	***		***		***	***	
Lokpa	***	***	***	***	***	Goussémassi	Soutoulouma	Gouhouloumassi	Yélengas	Yéringassi	Yéringassi
Yom	***	***	***	***	***	Morrum or Morra	Dobrohum	N'péra or Pirm	Yères	Yéringa	Yéringa
Bariba	***	Yansourérou or Kpanfirérou	***	***	***	Souannu or Faanrou	Danbourou	Kpika	***	***	Yansourérou Kpanfirérou or Kpanfourénou
Ditamari	***	***	***	***	***	Nongou	Touhoum	Tipèè or Epèrè	Kouyehoun or Diyèni	Yèyièmè or Diyiani	Yèyièmè
Dendi	***	***	***	***	***	Tchiré	***	***	***	***	Doundou Tchiré
Natemba	***	***	***	***	***	***	***	***	***	***	Tsémmou Noka
Wama	***	***	***	***	***	***	***	***	***	***	Bokiwinta

Table 1 continued

Ethnic group	Local name and denomination criteria										Generic name
	Provenance (Source)	Tuber shape	Roots density on tuber			Flesh color			Tubers' cluster		
			Sparse	Medium	Dense	Pure yellow	Pale-yellow	White	Separate tubers	Fused tubers at the neck	
Biali	***	***	***	***	***	***	***	***	***	***	Tayinbia
Sola	***	***	***	***	***	***	***	***	***	***	Bogwèna

***Not used as criteria

NARS National Agricultural Research Services

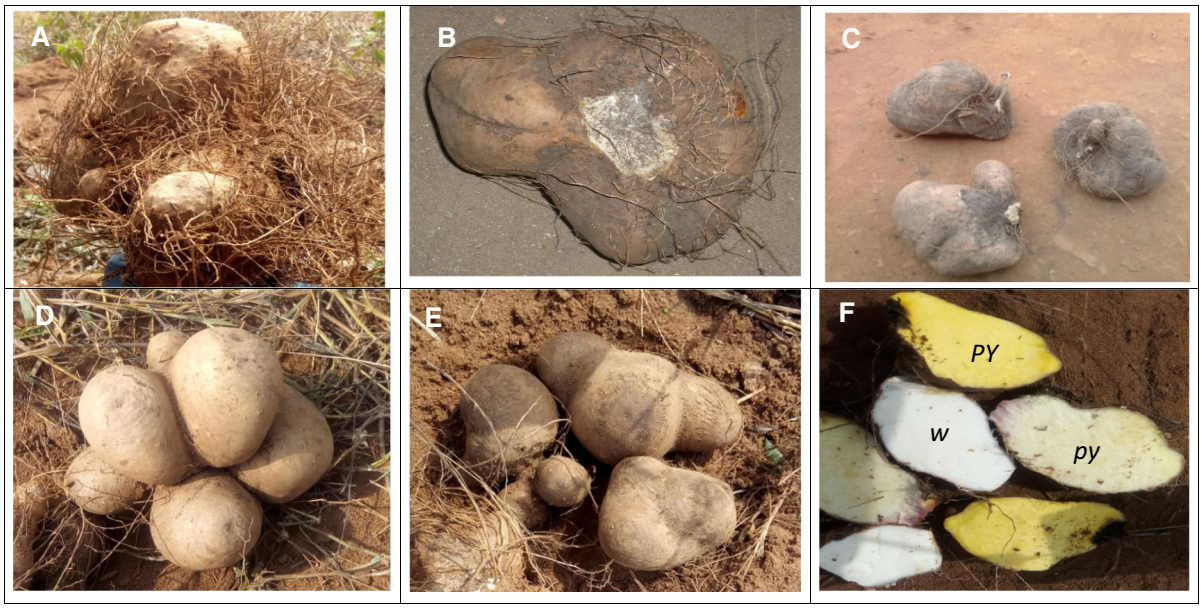

Fig. 2 Traditional naming and classification of *D. dumetorum* landraces using root density on tubers (**A**–**C**), tuber shape (**D**, **E**) and flesh color (**F**) criteria in some socio-linguistic groups in Benin. A: Olichan igba = thousand spines; B: Olichan méta = three spines; C: Konichan = without spines; D: Olo mou (shape of breast); E: Gbôta (shape of head of sheep); F: Pure yellow (PY), pale-yellow (py) and white (w) tubers. (Color figure online)

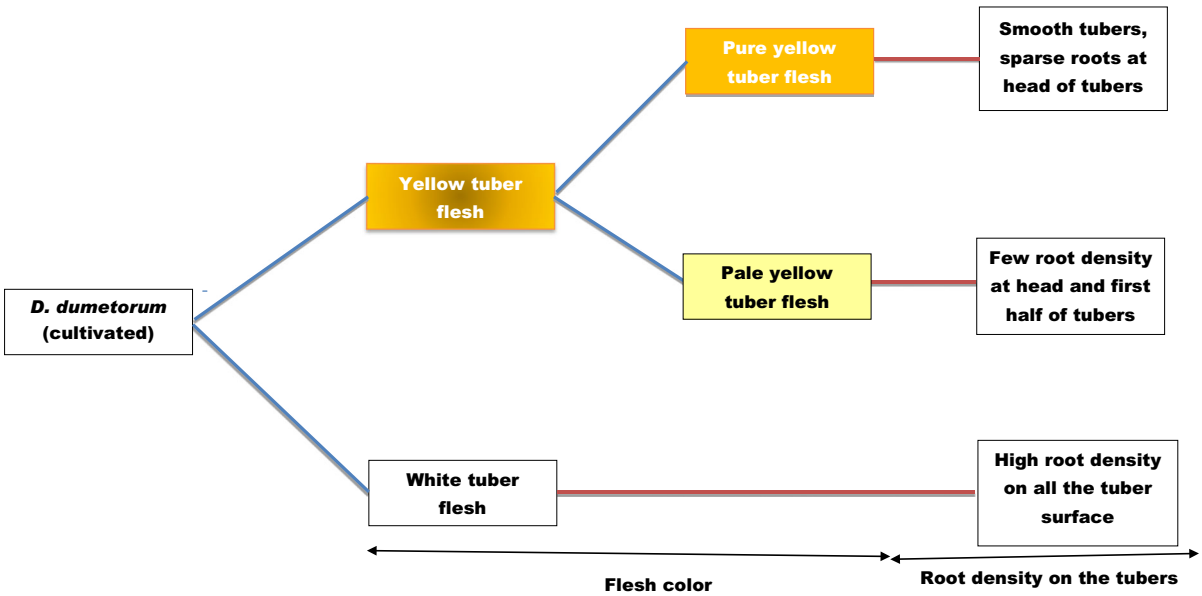

Fig. 3 Folk classification of edible *D. dumetorum* cultivars based on the two major criteria in Benin. (Color figure online)

the highest cultivar diversity with 16 cultivars inventoried followed by the central and northern Benin with respectively 11 and 8 cultivars documented. The quotation analysis revealed that the landraces *Kpoukpa*, *Léfèwéwé*, *Yansourérou* and *Olomousobolo* were the most cultivated *D. dumetorum* cultivars in the agroecological zone V. *Kpoukpa*, *Léfèwéwé* and *Lébétou* were the most known landraces in the agro-

Table 2 Major tuber characteristics of cultivated morphotypes of *D. dumetorum* in Benin

Morphotype	Reference cultivar	Other names of cultivars	Major tuber characteristics
White	Yansourérou kpika (Bariba)[a]	Léfé wéwé (Fon), Essou or Essourou foufou (Nago, Holli, Yoruba), Kpanfirérou kpika (Bariba), Yèyièmè tipèè or Epèrè (Ditamari), Yéringa N'péra or Pirm (Yom), Yéringassi gouhouloumassi (Lokpa)	Tubers in irregular form, dense roots and many tiny rootlets on all the surface of the tubers, rugourous tuber skin, white flesh
Pale yellow	Yansourérou danbourou (Bariba)	Lébétou (Adja), Yélengas soutoulouma (Lokpa), Yèyièmè touhoum (Ditamari), Yéringa dobrohum (Yom), Kpanfirérou danbourou (Bariba)	Rounded tubers, sparse roots, tiny rootlets only on half superior surface of the tubers, smooth tuber skin, pale-yellow flesh
Pure yellow	Yansourérou souannu (Bariba)	Léfé vovo (Fon), Essou or Essourou kpoukpa (Nago, Holli, Yoruba), Kpanfirérou faanrou (Bariba), Migoagban (Adja), Olomou sobolo (Nago, Holli, Yoruba), Bogwèna (Sola), Tayinbia (Biali), Bokiwinta (Wama), Tsémmou Noka (Natimba), Doundou Tchiré (Dendi), Yèyièmè nongou (Ditamari), Yéringa morrum or morra (Yom), Yéringassi goussémassi (Lokpa)	Oblong or rounded tubers, very rare roots at the head of the tubers and absence of rootlets on the surface, smooth tuber skin, pure-yellow flesh

[a]In parenthesis, the ethnic group in which the name is given

ecological zone VI. Only the cultivar *Agriki* was the most known variety in the agro-ecological zone VII. In the agro-ecological zone VIII, *Ayoléfé*, *Gounléfé*, *Léféwéwé* and *Léfévovo* were found to be the ones more used by local farmers. Finally, the landraces *Yansourérou* and *Yèyièmè* were the most abundant *D. dumetorum* cultivars in the area III, and only *Yéringassi* was more practiced by farmers in the agro-ecological zone IV. By summarizing all, it appeared that the southern and central agro-ecological zones were the most rich in *D. dumetorum* varietal diversity than the northern agro-ecologies (Table 3).

Finally, by mapping the distribution of cultivar diversity of *D. dumetorum* with regard to the three major morphotypes in diverse agro-ecological zones and localities surveyed in Benin, it appeared clearly that the pure yellow cultivars were the most widely cultivated in Benin (cf. Fig. 1). White *D. dumetorum* cultivars were almost exclusively cultivated in the central part of the country (mainly Collines Department) covering the agro-ecological zone V with southward extension to the agro-ecological zone VII. Besides, the pale-yellow cultivars, very restricted in cultivation, were found in the Central (Department of Glazoué) and South-Western (Department of Mono) parts of Benin covering the agro-ecological zones V and VI.

Farmer preference criteria in the choice of *D. dumetorum* cultivars

In total, twelve criteria were used by farmers throughout the agro-ecological zones surveyed in their choice of adequate *D. dumetorum* cultivar for production. These were good productivity of cultivars, color of the tuber chair (flesh), tuber size, abundance of branching tubers, cycle and port of the plant, low tutor requirement, good conservation aptitude, adaptations to soil poverty and to all soil types, resistance to pests and disease, resistance/tolerance to weeds development. The principal component analysis performed on these criteria as well on agro-ecological zones revealed that the first two axes were sufficient to explain almost all their variability (98.37% of the total variability). The Tables 4 and 5 show respectively the contributions of criteria and those of agro-ecological zones to the formation of the axes and their representativeness.

The simultaneous representation of criteria and agro-ecological zones using the first two factorial axes revealed two opposite groups of agro-ecological zones

Table 3 Diversity and importance of *D. dumetorum* cultivars in agroecological zones surveyed in Benin

Cultivar names	Ethnic group	Central agro-ecology	Southern agroecology			Northern agroecology	
		V	VI	VII	VIII	III	IV
Sakété	Adja	–	×	–	–	–	–
Gbota		×	×	–	–	–	–
Lébétou		–	××	–	–	–	–
Migoagban		x	x				
Ayoléfé	Wémé	–	–	×	×××	–	–
Gounléfé		–	–	×	××	–	–
Foufou	Holli	–	×	×	×	–	–
Kpoukpa	Nago	×××	×	×	×	–	–
Olichanigba		–	–	×	–	–	–
Olichanméta		–	×	×	–	–	–
Konichan		–	–	×	–	–	–
Chanchangni		–	×	×	–	–	–
Agriki	Idaasha, Holli, Nago	–	×	××	–	–	–
Olomousobolo		××	×	×	–	–	–
Léféwéwé	Agoun, Cotafon	×××	××	–	××	–	–
Léfévovo	Fon	××××	××	–	××	–	–
Yansourérou	Bariba	×	–	–	–	×××	–
Tanyinbia	Biali	×	–	–	–	–	–
Yèyièmè	Ditamari	×	–	–	–	××	×
Yéringassi	Lokpa	×	–	–	–	×	××
Tsémou-Noka	Natemba	×	–	–	–	×	–
Bokiwinta	Wama	–	–	–	–	×	–
Bogwèna	Sola	–	–	–	–	–	×
Yéringa	Yom	–	–	–	–	–	×
Doundou-Tchiré	Dendi	–	–	–	–	×	×
Total		11	12	10	6	6	5
			16			8	

× Quoted by 1–10% of interviewees; ×× quoted by 10–20% of interviewees; ××× quoted by 30–60% of interviewees; ×××× quoted by ≥ 70% of interviewees

in varietal preferences and choice of *D. dumetorum* cultivars (Fig. 4).

The first group includes the southern and central agro-ecological Zones V, VI, VII and VIII where the main preference criteria in *D. dumetorum* cultivar selection were the plant cycle, the port of the plant, the abundant branching of tubers, the low tutoring requirement, the good productivity, the color of chair (flesh), the good conservation aptitude and the size of tubers (Fig. 4). The second group constituted of northern agro-ecological Zones III and IV where the most important criteria used were the adaptability to all type of soil, the adaptability to soil poverty, the resistance to diseases and pests, and the resistance/tolerance to weeds of the cultivars. By summarizing all, plant morphophysiological characteristics and agronomic performances of cultivars motivated farmers of southern and central agro-ecological zones in their preference for cultivar selection while the adaptability of the crop to biotic and abiotic stresses determined the preference and choice of farmers in northern agro-ecologies.

Table 4 Contributions of criteria to the formation of the axes and their representativeness

Preference criteria in cultivar selection	Contribution			Representativeness		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Good_productivity	3.25	6.31	0.09	0.93	0.07	0.00
Color_Chair	3.29	7.16	1.36	0.92	0.08	0.01
Tuber_size	2.49	7.20	2.39	0.88	0.10	0.01
Abundant_branching_tubers	**11.14**	**43.40**	5.22	**0.86**	0.13	0.01
Plant_cycle	6.33	0.83	1.14	0.99	0.01	0.00
Port_plant	3.75	0.87	**55.74**	0.81	0.01	0.18
Low_require_tutoring	**11.82**	**9.06**	**18.36**	**0.95**	0.03	0.02
Good_conservation	0.60	1.20	0.89	0.85	0.07	0.02
Adapta_soil_poverty	**9.27**	**9.73**	0.05	**0.96**	0.04	0.00
Adapta_all_types_soil	**9.33**	**9.54**	6.30	**0.95**	0.04	0.01
Resist_diseases_pests	**11.80**	3.10	3.03	**0.98**	0.01	0.00
Weed_resistance	**26.94**	1.61	5.42	**0.99**	0.00	0.00

The criteria that contributions Ci are $\geq$ 8.33% on an axis are those which contributed to the formation of this axis and are represented on the axis only if their Cosinus^2 is $\geq$ 0.30 (all values in bold in the table)

Table 5 Contributions of agro-ecological zones to the formation of the axes and their representativeness

Agro-ecology	Contribution[a]			Representativeness[a]		
	Axis1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Zone V	12.30	4.12	**42.41**	0.94	0.01	0.05
Zone VI	12.94	**72.56**	4.32	0.82	0.18	0.00
Zone VII	2.61	6.00	**32.52**	0.77	0.07	0.14
Zone VIII	9.03	14.51	**19.25**	0.91	0.06	0.03
Zone III	**32.44**	2.76	0.00	**1.00**	0.00	0.00
Zone IV	**30.68**	0.06	1.50	**1.00**	0.00	0.00

[a]Agro-ecology that contributions Ci are $\geq$ 16, 66% on an axis are those which contributed to the formation of this axis and is representive of the axis only if their Cosinus^2 is $\geq$ 0.30 (all values in bold in the table)

Seed system in *D. dumetorum* and farmers' management strategies

The mode of acquisition of planting seeds (tuber seeds) of *D. dumetorum* remained traditional in all the growing areas surveyed in Benin. The widely used modality reported by farmers (100% of surveyees) was the retention on the previous harvest; the rest was devoted for domestic consumption or for sell. Indeed, before selling the harvested tubers, some producers collected the small ones and kept them as seeds for next season. Exchange and gift between family members, friends and neighbors were also practiced by farmers to acquire tuber seed (75% of surveyees).The third modality was planting tuber seed purchasing (25% of surveyees) from local traders. Indeed, before cooking the tubers, womens also collected from their marketed material the small ones with low income value and resold them to producers who used like planting seeds.

Ethnobotanical importance of *D. dumetorum* in Benin

Food use of D. dumetorum

In all the agro-ecological zones surveyed in the country, *D. dumetorum* was exclusively produced for human consumption. All the producers surveyed (100%) consumed it in their households. In general, *D. dumetorum* is preferentially consumed in boiled form. The Fig. 5 illustrates the process of preparation of tubers. Shortly, tubers were first cleaned by

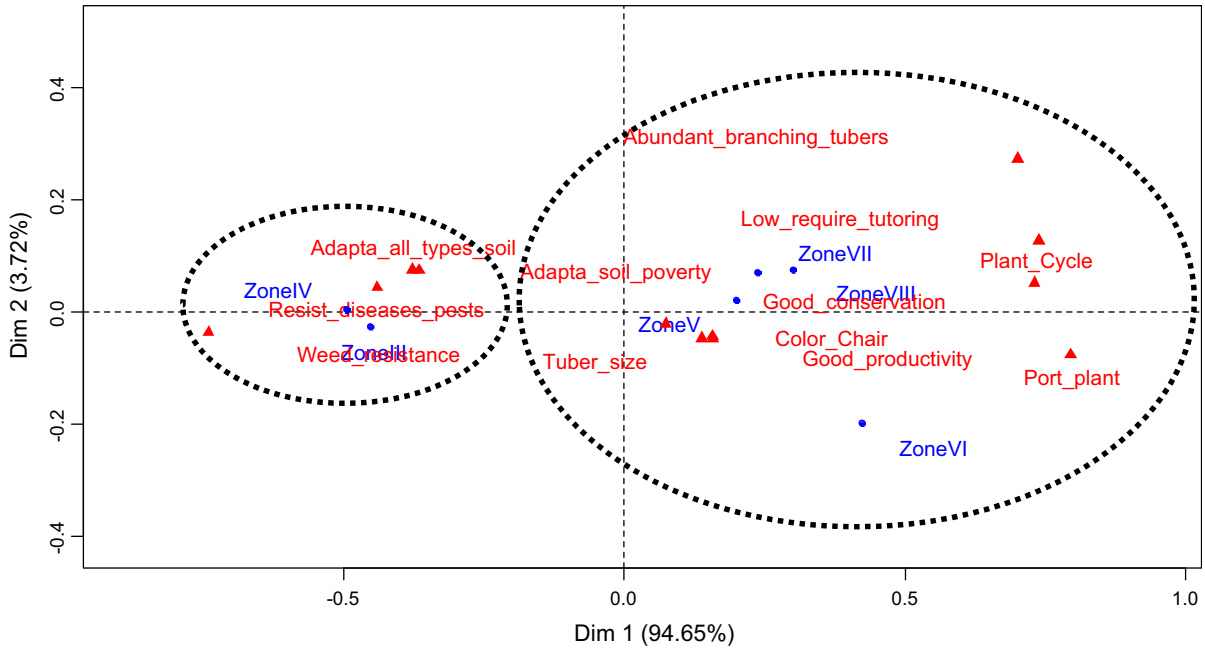

Fig. 4 Simultaneous representation of farmers' preferences criteria and agro-ecological zones using the first two factorial axes. (Color figure online)

removing roots and rootlets. After that, the tubers were cut and washed without being peeled.

According to farmers, the cooking is done overnight in simple water without adding salt. Consumption is only possible in the next day. This long cooking was reported to be necessary for removing all the harmful subtances that the tubers would contain and therefore preventing consummers from intoxication. To eat the boiled tubers, the skin was first removed with a home knife or directly by nails. In majority of cases, boiled tubers were eaten directly while some few farmers (2% of respondents) eat them with pepper, fried onion or simple oil. Other farmers (less than 1% of respondents) appreciated cutting boiled tubers into dices and incorporated them in the salad instead of using potato. A small percentage of farmers (1% respondents) first half-boiled tubers and fried them in oil. However, the result was reported to not be interesting like the case of *D. cayennensis-D. rotundata.* In contrast to this latter yam species, the major reported factor limiting *D. dumetorum* consumption in the country was its unaptitude or unsuitability to be pound into fufu, a widely appreciated dish by local populations, particularly in the Center and North Benin. In the whole study area, no other food product of *D. dumetorum* was reported in traditional culinary system as well in local agro-industry. Besides, no utilization of *D. dumetorum* in animal feeding was also reported.

Medicinal uses and magico-mystic importance of D. dumetorum

In the study area, *D. dumetorum* was also used to treat many diseases. In total, fourteen diseases/system disorders were reported by farmers (Fig. 6). The most important diseases treated by local communities using *D. dumetorum* concerned digestive system disorders (vomit, colic) followed by infections (malaria, headeach), circulatory system and metabolic disorders (high blood pressure, diabetes). Weight decline, eye diseases, icterus and skin disorders as well magico-mystic sicknesses were reported to be also treated by using *D. dumetorum*.

The main organs of *D. dumetorum* used to treat these diseases were leaves and tubers. Seven disorders are treated with tubers while seven other with leaves. No disease was reported to be treated simultaneously with leaves and tubers. The Table 6 shows the different plant organs with the specific diseases threated as well the diverse modes of preparation.

Fig. 5 Processing of *D. dumetorum* for food purpose in Benin (LaREGAME 2016): **A** Tubers cleaning by roots cutting, **B** tubers washing, **C** boiled tubers for selling and **D** tuber flesh ready to eat. (Color figure online)

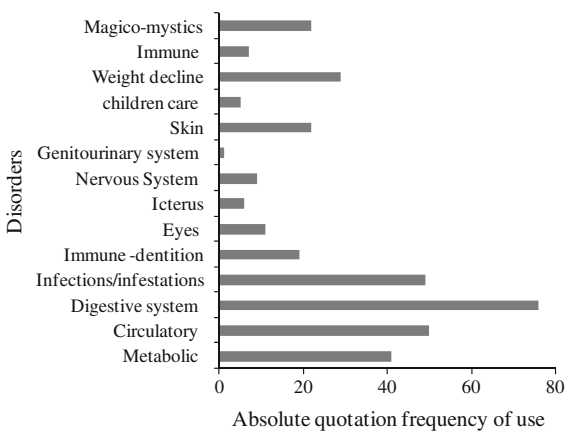

Fig. 6 Importance of diseases treated by *D. dumetorum*

Effect of agro-ecology and socio-demographic characteristics on overall use value of D. dumetorum

The analysis of covariance revealed that the overall use value of *D. dumetorum* was highly determined ($P < 0.000$) by the agroecological zone location, the socio-linguistic group and the age of interviewees (Table 7). In contrast, the effect of the sex on the overall use value was not significant. The interaction between agro-ecological zone and socio-linguistic group on the one hand and the interaction between agro-ecological zone, age and sex on the other hand influenced the overall reported use value of *D. dumetorum* by local farmers.

Table 6 Medicinal and magico-mystic uses of differents organs of *D. dumetorum*

	Plant organs used	Disorder treated	Mode of preparation/treatment
Medicinal uses	Tuber (white and yellow)	Cough	Soaking of tuber in alcohol, drink small glass twice a day
		Immunity system	Drink regularly soaking of tuber in alcohol
		High blood pressure	Soaking of tuber in alcohol, drink small glass twice a day
		Digestive system disorders (vomiting, colic)	Drink regularly soaking of tuber in alcohol
		Diabete	Eat regularly boiling tubers
		Weight decline	Plunder and extract liquid in combinaison with other plants
	Leaves	Reproductive system disorders	Triturate leaves and mix with traditional black soap (Koto) and wash with
		Skin diseases	Triturate leaves and mix with traditional black soap (Koto) and wash with
		Eye diseases	Triturate young leaves in water and put in eyes
		Malaria, icterus, headeack	Drink decoction or infusion of leaves
		Children care	Triturate leaves and mix with traditional black soap (Kôtô). Wash the head of baby in one way
		Dentition (teeth setting)	Drink decoction or infusion of leaves
		Inflammations	Drink decoction or infusion of leaves
Magico-mystic uses	First food taken at the beginning of the new year to prevent against ghosts and bad spirits		
	Tubers put on tombs as food to help dead people souls to pass in peace the long trip towards the next world		
	Tubers used in combinaison with other plants in mystic rituals		

Table 7 Effects of agro-ecology, socio-linguistic group, sex and age of farmers on overall use value of *D. dumetorum*

Factors	DF	SS	MS	F value	Pr (> F)
Agro_Zone	6	17.23	2.872	6.901	0.000***
linguis.group	17	28.09	1.652	3.971	0.000***
Sex	1	0.34	0.339	0.815	0.367 ns
Age	1	9.87	9.871	23.717	0.000***
Agro_Zone:linguis.group	29	22.17	0.764	1.837	0.006**
Agro_Zone:Sex	6	1.99	0.332	0.797	0.573 ns
linguis.group:Sex	9	1.18	0.131	0.315	0.969 ns
Agro_Zone:Age	6	1.64	0.274	0.658	0.684 ns
linguis.group:Age	14	8.43	0.602	1.448	0.128 ns
Sex:Age	1	0.34	0.339	0.814	0.367 ns
Agro_Zone:linguis.group:Sex	12	4.22	0.351	0.844	0.605 ns
Agro_Zone:linguis.group:Age	23	14	0.609	1.463	0.078 ns
Agro_Zone:Sex:Age	4	0.21	0.053	0.127	0.972 ns
linguis.group:Sex:Age	7	6.06	0.865	2.079	0.045*
Agro_Zone:linguis.group:Sex:Age	3	1.1	0.368	0.883	0.449 ns
Residuals	415	172.71	0.416	–	–

*Significant at 0.05;
**Significant at 0.01;
***Significant at 0.001

DF degree of freedom, *SS* sum of square, *MS* mean square; *F value* Fisher statistic, *Pr (> F)* probability superior at the probability value given in the table

Importance of D. dumetorum use and trading through agro-ecological zones surveyed

In the study area, *D. dumetorum* was reported to offer numerous uses to producers from fooding to medicinal purposes. Besides, *D. dumetorum* trading importance varied among surveyed agro-ecologies. The principal component analysis showed that the first two components explained 84.05% of the overall variability of *D. dumetorum* uses and trading as well overall variability in agro-ecology (Fig. 7). The combined analysis of the results revealed a divergent pattern of the uses of this crop among agro-ecological zones. In the agro-ecological Zones V, VI and VII, farmers used *D. dumetorum* especially for food and medicinal purposes. In other hand, local people in Zone VIII used the species for food and magico-mystic (potion) purposes. In the Zone III, *D. dumetorum* is used for magico-mystic purposes while farmers of the Zone IV used it for trade and medicinal purposes.

Importance of D. dumetorum use and trading among sociolingustic groups

The principal component analysis revealed that 78.53% of the overall variability in the use category and trading of *D. dumetorum* was due to the divergence among sociolingustic groups memberships of farmers (Fig. 8). People belonging to *Holli*, *Agoun*, *Fon*, *Wémè*, *Nago* and *Mahi* sociolingustic groups used the species for food, magico-mystic purposes and were mostly involved in *D. dumetorum* trading. *Adja* and *Idaasha* people mostly used *D. dumetorum* for food, magico-mystic purposes and traditional medicine. *Sola*, *Natemba*, *Wama*, *Cotafon*, *Lokpa*, *Bariba*, *Yom* and *Dendi* people used *D. dumetorum* for traditional medicine purposes and were also involved in its trading while *Biali* and *Ditamari*, in addition to their involvement in trading, were also found to use *D. dumetorum* essentially for magico-mystic purposes. Finally, *Bariba*, *Yom* and *Dendi* people used *D. dumetorum* also for magico-mystic purposes.

Pattern of D. dumetorum use following the age of interviewees

The principal component analysis of *D. dumetorum* use pattern and trading following the age range of interviewed farmers (Fig. 9) showed that the young farmers involved in the cultivation used *D. dumetorum* mainly for food purposes but some of them were also involved in its trading. Adult people produced and used *D. dumetorum* mainly for food and trading across agro-ecological zones. But they also used very secondary *D. dumetorum* for medicinal and magico-mystic purposes. In contrast, old people used *D. dumetorum* especially for magico-mystic and traditional medicine purposes.

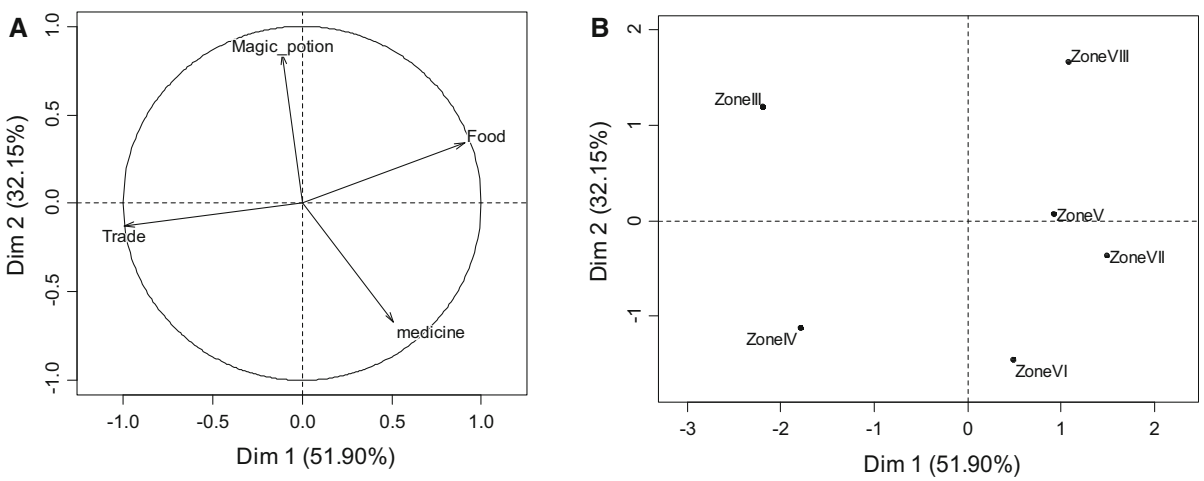

Fig. 7 Principal component analysis of the variability in uses and trading characteristics and the distribution of agroecology of *D. dumetorum* cultivation in Benin. **A** Projection of uses and trading characteristics in the plane formed by PCA axes 1 and 2; **B** Biplot representation of the distribution of agroecological zones in *D. dumetorum* cultivation

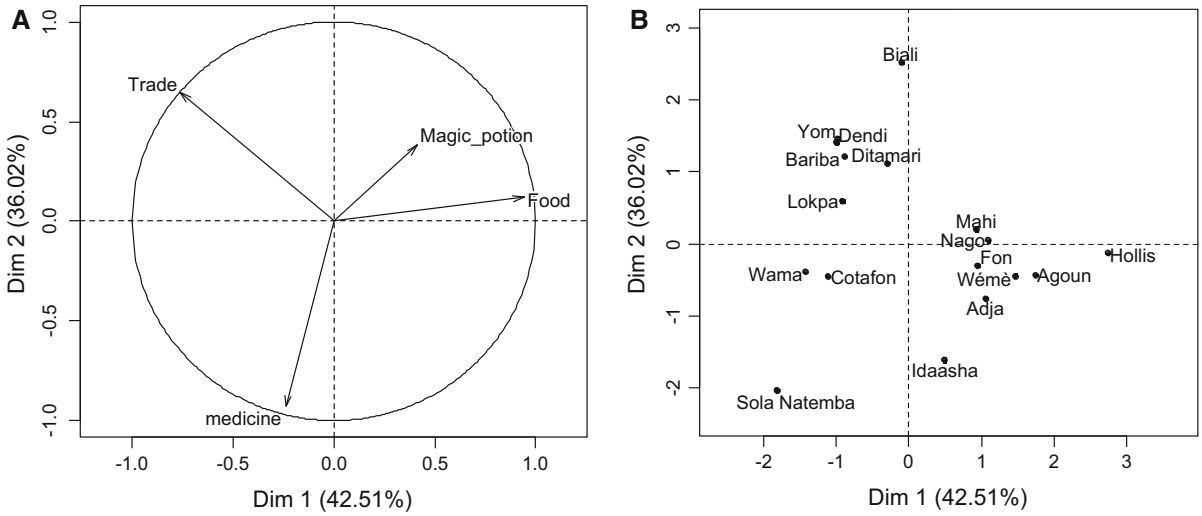

Fig. 8 Principal component analysis of the variability in uses, trading importance and the distribution of farmers' sociolinguistic groups involved in *D. dumetorum* cultivation in Benin. **A** Projection of uses and trading characteristics in the plane formed by PCA axes 1 and 2; **B** Biplot representation of the distribution of farmers' sociolinguistic groups involved in D. *dumetorum* cultivation

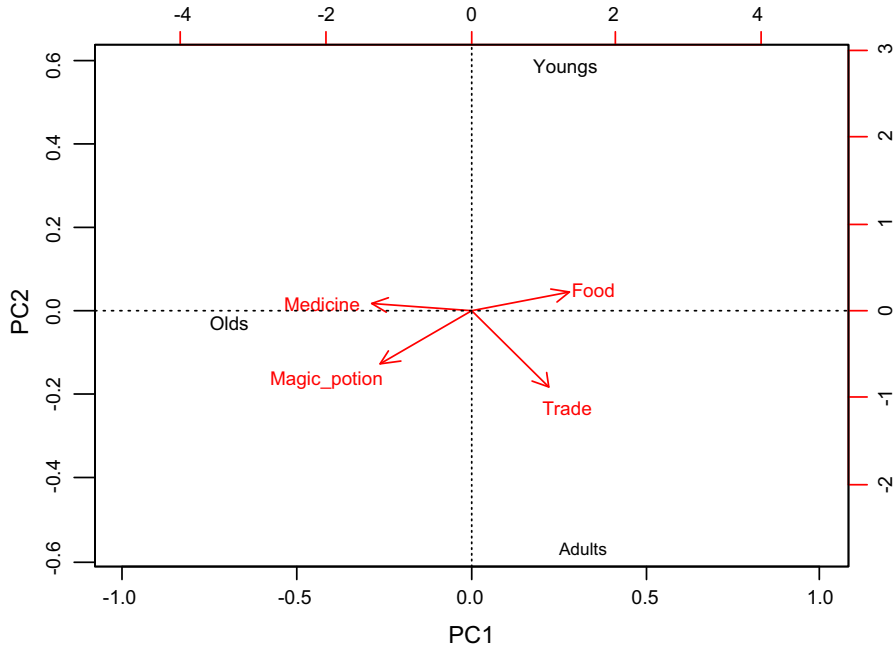

Fig. 9 Principal component analysis of *D. dumetorum* use pattern and trading following the age range of farmers involved in *D. dumetorum* cultivation in Benin

Wild morphotypes of *D. dumetorum*

Diversity and distribution

In all agroecological zones surveyed, wild morphotypes (WM) of *D. dumetorum* were also reported to be exploited by farmers. In contrast to the cultivated cultivars, they were reported to be toxic. In the whole study area, the majority of farmers (88%) had a good knowledge on the WM while only 12% ignored them. The quotation assessment of WM of *D. dumetorum* revealed that people recognized them more in the agroecological zones III, IV and V than in the other ones (Fig. 10). The Fig. 11 illustrates the differences

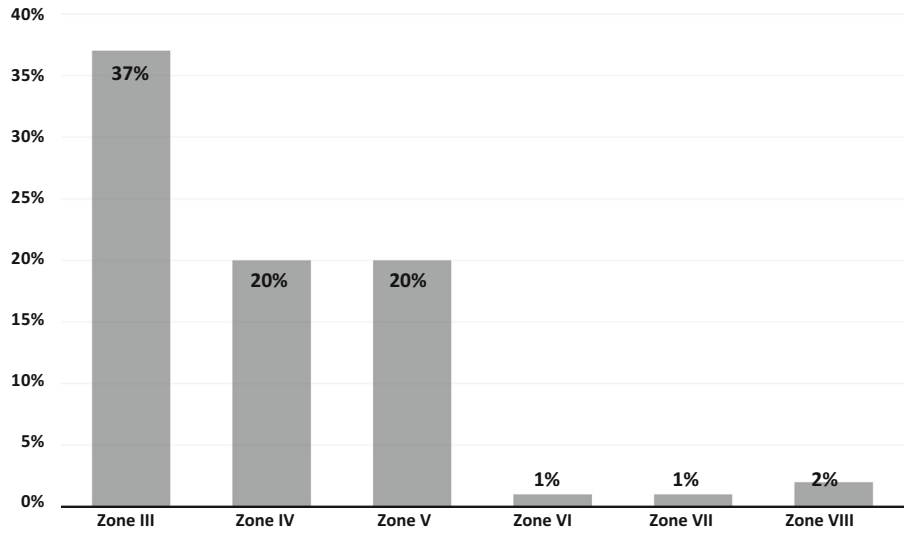

Fig. 10 Quotation frequency of wild morphotypes of *D. dumetorum* in agro-ecological zones of Benin

Fig. 11 Morphological differences between cultivated and wild *D. dumetorum* tubers

between tubers of cultivated and WM of *D. dumetorum*. Besides, among these farmers who knew these WM, only few were able to name them properly using specific vernacular names; the others named them just as ''wild'' *D. dumetorum*.

Globally, ten different farmer-named WM were recorded through the study area. These were *Goudougoudou, Glibitchi, Gbégbé, Egouechou, Odoguidjan, Diguimômô, Kpanfirérou gbegourougia, Kunkpalouyéoun, Mongorou* and *Kpatchahè*. The assessement of the recorded WM diversity revealed that the agro-ecological zones V and the zone III hosted the largest diversity with respectively six and five WM inventoried (Fig. 12). They were followed by the agroecological zones VI, VII, VIII with respectively four WM. The agro-ecological zone IV with two WM reported was the least rich zone in WM diversity.

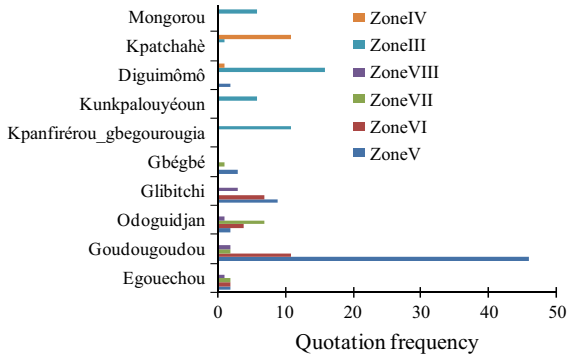

Fig. 12 Abondance and distribution of wild morphotypes of *D. dumetorum* through the agro-ecological zones surveyed. (Color figure online)

Differential characteristics of wild morphotypes of D. dumetorum

According to farmers' description, the WM differed among them and from the cultivated forms of *D. dumetorum* at diverse levels. These were mainly related to the tuber characteristics such as the size, the pubescence, the color of the flesh and the bitterness as well the presence of fine spines on tuber roots/routlets on the tubers and the spontaneous growth ability of the plant. The principal component analysis of the morphological characteristics of WM of *D. dumetorum* revealed that small tubers with spines as well the large and very pubescent tubers were, in opposite way, highly correlated with the first axis while the bitter taste was highly correlated with the second axis and in opposite way with the spontaneous growth ability and the white-snow flesh color. The simultaneous projection of the WM and their characteristics in the first two factorial axes (Fig. 13) indicated that the WM *Egouechou*, *Odoguidjan* and *Gbegourougia* were mainly characterized by the production of small tubers with spines while *Diguimômô Mongorou, Kpatchahè* and *Gblibitch* in contrast produced large and very pubescent tubers. Besides, *Kunkpalouyéoun* was the WF with very bitter tuber taste while *Goudougoudou* was characterized by its very quick spontaneous growth and a white snow color.

Management and uses of wild morphotypes of D. dumetorum

The WM grow spontaneously and are most often found in the forests/savannah (49% of respondents), abandoned fallows (40% of respondents) as well in fields (11% of respondents). According to the farmers, the WM found in fields are usually eliminated before flowering (60% of the producers) or after flowering (40% of the producers). This management approach of WM in their fields allowed farmers to avoid contamination of their harvest with wild tubers of *D. dumetorum.*

The usefulness of wild forms was not known to all producers. For 58% of the producers who were able to identify them, they would be of no utility. Some others, however, recognized their usefulness and their exploitation in certain rituals (19% of producers) and in traditional medicine (8% of producers). Thus, decocting wild tubers in alcohol mixed with other plants would inhibit their toxicity and this decoction could be used for treating severe cough, the cancer of the uterus and would stop hiccups in a dying person. In all the areas surveyed, no food/feed use of these wild forms were reported by farmers. However, this toxicity is exploited to combat animals that ravage fields such as monkeys and oxens.

Discussion

In this study, we explored the diversity, distribution and the ethnobotanical importance of cultivated and wild genetic resources of *D. dumetorum*, an underutilized but valuable yam species in Benin. The results documented here revealed that, despites the relatively neglected status of this yam crop in Benin (Dansi et al. 2012) farmers had developed valuable knowledge and experiences on management and use of its genetic resources. This indigenous knowledge is useful for conservation, improvement and valorization of *D. dumetorum* in Benin.

Varietal diversity and farmer management of cultivated *D. dumetorum* in Benin

In the study area, farmers named and identified *D. dumetorum* cultivars according to their phenotypic characteristics as well their origin. Folk taxonomy is a

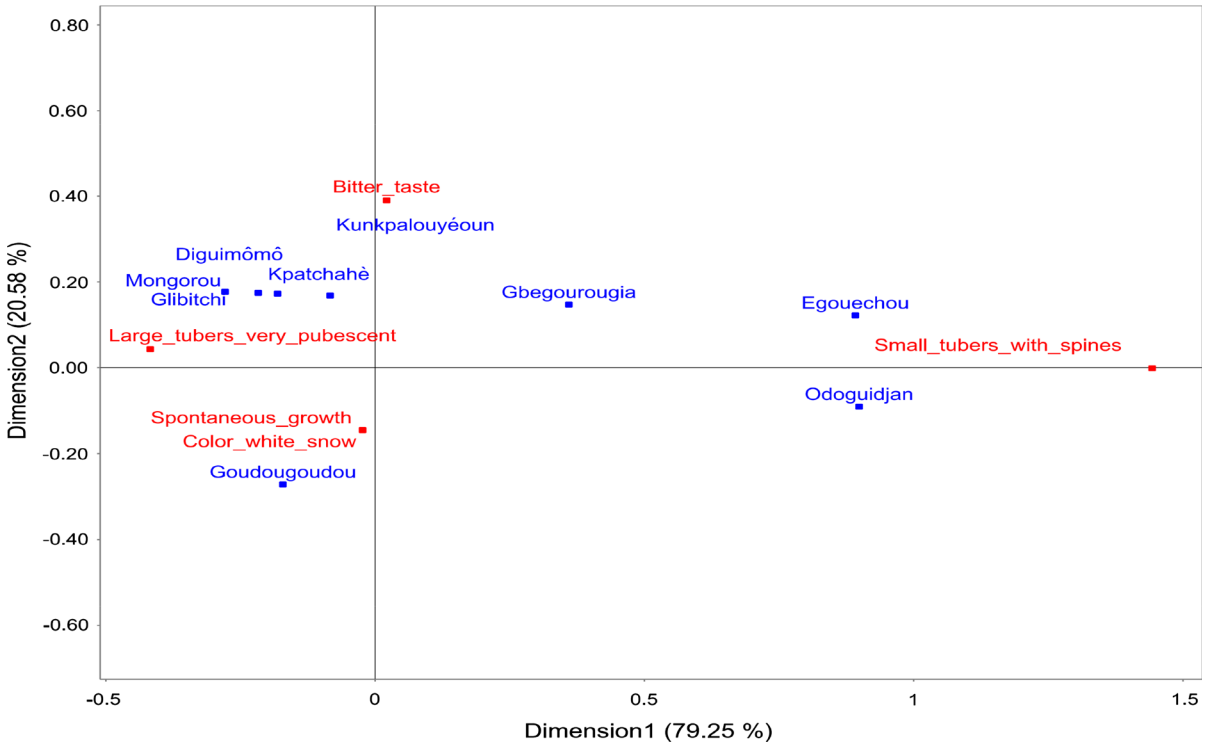

Fig. 13 Simultaneous representation of the morphological characteristics of wild related forms of *D. dumetorum* in the factorial plan 1 and 2. (Color figure online)

common farmer practice in traditional management of crop genetic resources and has been well documented in many crops, including Guinean yam (Loko et al. 2013), cassava (Kombo et al. 2012; Sambatti et al. 2001), fonio millet (Adoukonou-Sagbadja et al. 2006), enset (Tsegaye and Struik 2002), sorghum (Mekbib 2007; Missihoun et al. 2012a) and traditional leafy vegetables (Dansi et al. 2009). Here, the first common criteria in naming and grouping cultivars reported by farmers was the flesh color of *D. dumetorum* tuber (white, pure yellow and pale yellow). This finding is in agreement with that reported in Nigeria by Ukpabi (2015). However, in addition to this criteria, Beninese farmers also used other phenotypic criteria such as the root density on the tubers in naming and classifying *D. dumetorum* cultivars. This suggests that, in the study area, *D dumetorum* farmers, especially those of Holli and Nago tribes in South-eastern and Central Benin, have developed a good knowledge on this yam species. If the development of tuber roots is considered as stable trait and help a good cultivar identification/grouping, the shape of the tuber was reported by farmers as less efficient as it depend on soil characteristics such as the structure and the fertility.

At overall, 25 farmer-named cultivars of *D. dumetorum* have been inventoried through all the agroecological zones surveyed in Benin. As it is now well known, the linguistic polymorphism observed accross the study area may lead to an over- or under-estimation of varietal diversity since different varieties can have the same local name while the same variety can also receive different local names (Adoukonou-Sagbadja et al. 2006). Therefore, different cultivars with the same name and also same cultivar with different names can exist among these 25 farmer-named landraces. Doubloon in Guinea yam cultivars have been well reported in Ethiopia (Tamiru et al. 2008), in Ghana (Otoo et al. 2009) as well in Benin (Loko et al. 2013). Some authors like Agre et al. (2015), Kombo et al. (2012), Tumuhimbise et al. (2012) also reported the presence of homonyms and synonyms in other tuber crop like cassava (Tumuhimbise et al. 2012). However, this varietal diversity recorded in *D. dumetorum* is far lower than that reported in the complex *D.*

cayenensis–D. rotundata in Benin (Dansi et al. 1999; Loko et al. 2013), suggesting clearly less intensive farmer traditional selections during the domestication/cultivation history of this yam crop. In Benin, the 25 farmer-named *D. dumetorum* cultivars inventoried can be grouped into three major morphotypes based on farmers' description. This finding is in agreement with that of Ukpabi (2015) in Nigeria confirming that flesh color is clearly a widely used parameter in naming and managing diversity by farmers.

The southern and central Benin were found to hold the highest varietal diversity than the north (16 and 11 cultivars, cf. Table 3). In these areas, the agro-ecological zones VI, V and VII appeared to be the most diversified. Besides, all the three major cultivated morphotypes were found in these areas. This finding is not surprising as these zones were and remain the most important in terms of production, consumption and trading of *D. dumetorum* in Benin. This unequal distribution of diversity with hotpots in areas where cultivation is traditionally intensive is already reported in neglected crops such as enset (Tsegaye and Struik 2002; Tesfaye and Lüdders 2003), fonio millet (Adoukonou-Sagbadja et al. 2006) or Kersting's groundnut (Assogba et al. 2015). Globally, pure yellow cultivars appeared to be the most widely cultivated in Benin (cf. Fig. 3). The same observation has been reported in *D. dumetorum* production areas in Nigeria (Ukpabi 2015). The restricted importance of other morphotypes in cultivation could certainly be related to their low market value comparably to pure yellow cultivars well appreciated by consumers.

Farmers' preference criteria in selecting *D dumetorum* cultivars for cultivation and use relied on plant attributes and adaptation to environmental stresses. The authors like Adoukonou-Sagbadja et al. (2006), Kombo et al. (2012) as well Loko et al. (2013) reported similar observations. As it has been well stressed on yam by Tamiru et al. (2008) in Ethiopia, such farmers' practices contitute salient features in traditional farming system in the tropics, especially in South-Saharan Africa. Furthermore, farmer preferences for cultivars clearly differed between agro-ecologies. In this study, we found that plant morphophysiological characteristics and agronomic performance motivated mainly farmers from southern and central agro-ecologies in their preferences for cultivar selection while the adaptability of the crop to biotic and abiotic stresses determined farmers' choice in northern agro-ecologies. This difference in diversity management approaches for preferences' expression and cultivar selection in *D. dumetorum* could be explained by the divergence in production objectives: the cultivation is mostly market-oriented (income needs) in the south and centre of the country but, in the north, it is mainly devoted for agricultural resilience and food security.

Three modalities were observed for seed system management in the study area: self production (i.e. retention on the previous harvest), seed exchange and gift and seed acquisition from traders. These are agricultural practices commonly observed in traditional farming system and have been well documented for several neglected or underutilized crops (Adoukonou-Sagbadja et al. 2006; Tesfaye and Lüdders 2003; Orobiyi et al. 2013; Agre et al. 2015; Assogba et al. 2015). In this trend, Dansi et al. (2010) explained that friendry exchanges and gift of planting material serve to strengthen social links and cohesion in local communities. In contrast to others, planting tuber seed purchasing is an increasing practice in *D. dumetorum* since the recent market development. This has created a potential market for seed tubers and important networks between farmers and local traders. Futher investigation is needed to deeply evaluate the economic potential and market attributes of this crop.

Ethnobotanical importance of D. dumetorum in producing area of Benin

Since several decades, yam is well known as an important food security crop of major economic and sociocultural importance in sub-Saharan Africa, particularly in West-African yam belt (Coursey 1967; Ayensu and Coursey 1972). The present study, conducted on *D. dumetorum* in Benin, confirmed such observation and cleary revealed different pattern of uses of this species among the agro-ecological zones surveyed. Indeed, in the study area, *D. dumetorum* was used especially for food, medicinal and magico-mystic purposes. It also provided important incomes to farmers, particularly in the southern part of Benin when it is produced for sell. The same observations were reported for plants with multiples uses like fonio millet (Adoukonou-Sagbadja et al. 2006), Kersting's groundnut (Assogba et al. 2015), enset (Tesfaye and Lüdders 2003) and chili (Orobiyi et al. 2013) for

which, despites its neglect status, local people have devoted high importance.

Most of farmers used *D. dumetorum* mainly for food and trade. This suggest that producers knew well about its nutritional value and its valorization can mostly contribute to food security and improved incomes for local farmers in Benin. In all the survey areas, *D. dumetorum* was consumed directly as boiled tuber. This observation partly corroborate that observed in Nigeria where in some regions the boiled yam was only eaten with oil palm or local pepper soup (Ukpabi 2015). Besides, the results also revealed the absence of traditional as well modern technological processing of *D. dumetorum* in Benin. For instance, the unsuitability of *D. dumetorum* tuber to be pounded, as already reported elsewhere (Degras 1993; Rees 1972; Ukpabi 2015), limits its production and consumption comparably to the Guinea yam. However, *D. dumetorum* is well appreciated and its food and market values are increasing, notably in urban centres in the southern part of the country.

The uses of *D. dumetorum* in folk medecine were clearly confirmed by the present study. Twelve different diseases (skin and eyes diseases, icterus, sexual troubles, malaria, diabetes, etc.) treated by tuber and leaves of *D. dumetorum* were reported from this study. According to Luka et al. (2012), Ogbunugafor et al. (2014) and Sonibare et al. (2010), *D. dumetorum* possesses hypoglyceamic, hypolipideamic and hypocholesterodeamic activities. Besides, Iwu et al. (1990) found olso that dioscoretine content in *D. dumetorum* can be used advantageously as a hypoglyceamic agent to reduce the blood glucose. This can justify its use by local populations to treat diabetes and weight decline. Specific scientific investigations are therefore needed to identify/isolate the active molecular principles that underline such ethnomedicinal use of *D. dumetorum* by local farmers.

It is already well proven that socio-cultural factors and traditional management impact the diversity in crop species (Adoukonou-Sagbadja et al. 2006; Missihoun et al. 2012b; Assogba et al. 2015; Zavinon et al. 2018). In this study, we tested the effects of such factors as well the agro-ecology on overall use value of *D. dumetorum*. Our study revealed that the agro-ecological zone, the socio-linguistic group and the age of interviewees had significantly influenced the overall use value of *D. dumetorum.* In contrast, no significant effect was observed for sex (gender) of interviewees, indicating that both men and women well used the crop. However at production level, the results showed nonetheless that *D. dumetorum* was essentially cultivated by mens, confirming the recent observation by Siqueira et al. (2014) in Brasil on water yam *D. alata*. The study revealed that young farmers (under 50 years), the most physically active community members, were less involved in *D. dumetorum* cultivation as this yam species is less attractive to them comparably to the complex *D. cayennensis-rotundata*, the most culturally and economically important yam in the world, especially in West-Africa (Dansi et al. 1999; Adoukonou-Sagbadja 2001). Therefore, the majority of farmers involved in *D. dumetorum* cultivation was aged people. This finding confirms recent observation by Ukpabi (2015) in Nigeria who showed that young Nigerian farmers, especially in the northern states, regarded *D. dumetorum* crop as a source of food only for their aged parents or grandparents. As it has been stressed by Adoukonou-Sagbadja et al. (2010) on fonio millets, farmers awarenesses are clearly required if all conservation and valorization concerns of this crop have to be met and its production being brought up to the same standard as that of the major yam crops, especially the Guinean (*D. cayennensis-D. rotundata* complex) and Water (*D. alata*) yams.

Farmer knowledge and use of wild D. dumetorum in Benin

The exploitation of wild plant genetic resources, especially the crop wild relatives, is a very ancient and common traditional practice in rural communities. These wild plants have special significance in the livelihoods of tribal people as they are gathered for food, nutrition and medicinal purposes (Rana et al. 2012). In many tribal communities worldwide, such tradition of gathering plants for different human uses still persists until today (Maikhuri et al. 2004; Lentini and Venza 2007; Ladio and Lozada 2009; Binu 2010; Kargıoğlu et al. 2010; Rana et al. 2012). The present study confirmed this feature. Indeed, although wild *D. dumetorum* was not exploited for food due to the bitterness of its tubers, the results showed that local producers have developed significant knowledge in exploiting wild morphotypes of *D. dumetorum* in ethnomedicine and certain traditional rituals. These knowledge are most important in northern and central agro-ecologies than the southern ones.

Wild crop relatives are important genetic resources for crop improvement in terms of resistence genes (Galván et al. 1997; Adoukonou-Sagbadja et al. 2010). In this study, many WM of *D. dumetorum* were recognized by farmers and may constitute an important asset for breeding programs on this underutilized but valued yam crop in Benin. Indeed, they may be an interesting source of new alleles and new allele combinations which could be useful to broaden the genetic basis of cultivated genepool. It is therefore important that these genetic resources are preserved to prevent genetic erosion and facilitate their further uses. Our study is however limited to a simple inventory and farmer description of WM. Specifically larger study is necessary to address this question on a deeper manner.

Conclusion

The present study revealed that this yam crop has important ethnobotanical importance in Benin. A subtancial varietal diversity is still maintained by farmers that was found to be unequally distributed through the producing agro-ecological zones. The pure yellow cultivars were found to be the most popular morphotype in the country. Farmers' preferences in cultivars' selection are based on criteria that vary primarily by agro-ecology. Seed management system remain traditional. In the producing areas, the crop is exploited mainly for food (household consumption) and trade but also in traditional medecine or for magico-mystic purposes. Furthermore, local farmers had also developed knowledge to exploit the wild genetic resources of *D. dumetorum*. Despite its reported neglected status, *D. dumetorum* is found to be well appreciated, indicating that its potential can be economically valued for food and nutritional security necessity in Benin and elsewhere. This can be effective if integrated strategies for the sustainable conservation and use of *D. dumetorum* genetic resources are developed. As it has been stated elsewhere, these strategies may include intensive research, raising farmers' awareness, and key development actions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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