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Yam (*Dioscorea rotundata* Poir and *D. cayenensis* Lam complex) in the Traditional Agriculture of Benin: Present-Day Cultivar Diversity and Farmers' Perception on their Tolerance to Tuber Dry Rot caused by the Nematode *Scutellonema bradys*

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A B S T R A C T

In Benin, yam (*D. cayenensis- D. rotundata* complex) hold a prominent position in the diet and economic sector. Dry rot caused by *Scutellonema bradys* is one of the major concerns affecting diversity and resulting in significant losses to farmers. To assess the current cultivar diversity in the traditional agriculture and the importance of the cultivars perceived by the farmers as tolerant to tuber dry rot caused by the nematode *Scutellonema bradys*, 42 villages and six major markets were randomly selected from the four known yam diversity zones in Benin and surveyed using participatory rural appraisal. The results still revealed the presence of great yam diversity in Benin hence rejecting the statement of previous study according to which they will be a strong degradation of cultivar diversity in Benin by 2017-2018 with probably severe consequences on the food security of the population. Subject to synonymy, 640 cultivars were recorded. The number of cultivars varied from 4 to 39 per village (22 on average). The Shannon diversity index was 5.28 bits. In comparison with the study conducted five years ago, no significant reduction in the total number of cultivars per village was noted. Out of the existing diversity, only 10 cultivars morphologically distinct (UPGMA cluster Analysis) are perceived as tolerant to nematode and were even absent on the markets surveyed as they have no market value. Considering the scarcity of the yam cultivars tolerant to nematodes and the necessity to have a regional pool of such genotypes for the improvement of market varieties, the extension of such study to the other countries of West Africa yam belt is recommended.

Keywords

Benin, diversity, nematode, *Scutellonema bradys*, Yam

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Introduction

Yam is the most predominant basic starch in sub-Saharan Africa specifically called West African Yam Belt (Fu *et al.*, 2011; Demuyakor *et al*., 2013). Its tubers are rich in carbohydrates, proteins, vitamins and mineral salts (Degras, 1986; Olajumoke *et al*., 2012). Various studies reported on its importance on several plans including diet (Ayodeji *et al*., 2012; Oluwole *et al.*, 2013), energy (Scarcelli, 2005), socio-cultural (Mignouna and Dansi, 2003; Osunde and Orhevba, 2009), worship (Baco, 2007), pharmacopoeia (Aké Assi, 1998) and even economic (Asiedu, 2003; Olorede and Alabi, 2013). According to FAOSTAT (2017), of the 68.13 million tonnes of world production, 94.53% comes from West Africa and only 5.17% from Benin, the fourth largest producer after Nigeria, Ghana and Ivory Coast. A number of constraints justify Benin situation. These include lower soil fertility (Agbidinoukoun, 2013; Ettien *et al*., 2013), climate variability, conservation issues, lack of effective cultivars, poor seed and market organization and pest and disease attacks that cause yield losses (Loko *et al*., 2013a) negatively affecting farmers' income. Of these, plant parasitic nematodes attacks are of major importance. Among yam nematodes, *Scutellonema bradys* causing dry rot of yams is the most abundant in Benin (Baimey *et al.*, 2009). Its attacks result in a significant losses during storage (Bridge, 1982), a significant market value's reduction of tubers (Bridge *et al*., 2005) and predispose them to secondary rot and rapid deterioration (Adesiyan *et al*., 1975). Since yam multiplication is mostly vegetative, the use of infested tubers as planting material is a potential source of inoculum (Quénhervé, 1997). At a time when food security is a key component of poverty alleviation, efficient management strategies against these plant parasitic nematodes are imperative. According to Dansi *et al.*, (2013a), the use of tolerant or resistant cultivars is the less costly and environmental friendly way to minimize the effects of agronomic, biotic and abiotic constraints related to yam production. Therefore, it is important to identify within the existing yam diversity, the cultivars tolerant to nematodes as the existence of such cultivars has been signaled by farmers (Loko *et al.*, 2013b).

In 2011, a countrywide spatial distribution of yam diversity analysed using ordinary Kriging (Bilgili, 2013) indicated that in absence of appropriate actions, Benin will experience by 2016 and beyond, a strong degradation of cultivar diversity in all zones with probably severe consequences on the food security of the population (Loko *et al*., 2013b). If this statement hold true, a significant difference is expected between the present-day cultivar diversity and the one recorded six years ago (Loko *et al*., 2013b).

The objectives of this study were three folds:

- -Conduct an ethnobotanical survey in both production zones and markets to assess the present status and the evolution of yam landraces' diversity in the country.
- -Identify the cultivars known to farmers as tolerant to tuber dry rot caused by the nematode *Scutellonema bradys.*
- -Carry out, because of synonymies and homonymies, the morphological characterisation of the nematodes-tolerant landraces for their classification into morphotypes.

Materials and Methods

Study area

Situated in West Africa between the latitudes 6°100 N and 12°250 N and longitudes 0°450 E and 3°550 E (Akoègninou *et al*., 2006), the Republic of Benin covers a total land area of 112,622 km^2 with a population estimated at about 10 million (INSAE, 2013). The country is partitioned into 12 departments (Figure 1) inhabited by 29 ethnic groups (Adjatin *et al*., 2012).

The south and the center are relatively humid agro-ecological zones with two rainy seasons and mean annual rainfall varying from 1,100 to 1,400 mm/year (Yabi and Afouda, 2011). The north is situated in arid and semi-arid agro-ecological zones characterized by unpredictable and irregular rainfall oscillating between 800 and 950 mm/year with only one rainy season. The country is partitioned into four agro-ecological zones (Affokpon, 2011) namely Guinea savannah zone, Sudan savannah zone, sub-humid savanna zone and humid forest zone. The Guinea savannah zone located between latitudes 8 ° and 11 ° North is characterized by a bimodal rainfall with an annual average rainfall of 1200 mm; an average temperature varying between 25 and 29°C and a relative humidity varying between 69 and 97%. The Sudan savannah zone located between latitudes 11 ° and 12 ° north is the most northern part of the country with an unique rainy season from May to September. The climate is dry with a rainfall less than 1000 mm, an average relative humidity of 54.9% and a high temperature between 30°C and 42°C. The sub-humid savanna zone covers the vast majority of the Center-South diversity zone with a rainfall between 1100 and 1200 mm. The humid forest zone, it is the most southerly with a heavy rainfall that sometimes goes beyond 1200 mm (Gnanglè *et al*., 2011).

Yam is produced throughout the country apart from the far north because of drought and the far south due to ignorance of cultural practices. Based on morphological characterization of selected cultivars collected throughout the country and the types of the guinea yam cultivars produced, the yam producing area of the country was partitioned into four zones of diversity (Loko *et al*., 2013a). These are: Bariba cultural area (Northeast); Donga zone assembling the Yom, Ani, Lokpa and Kotocoli cultural areas; Atakora zone (far Northwest) grouping the Wama, Natimba, Ditamari, Berba and M'bermin cultural areas;and the Central zone with the cultural areas Fè, Fon, Idatcha, Mahi and Tchabè.

Site selection and survey

Based on the importance of their yam production, their richness in cultivars and their geographical localization, 42 villages (Figure 1) were randomly selected and surveyed. In each village, 20 well known producers were assembled with the help of the chief of the village and his assistants. At each village, a well-illustrated introduction of the damage caused by the yam nematodes was done and the producers were invited to list (vernacular names) the known cultivars of the village. The distribution and extent of these cultivars were assessed using the foursquare analysis method following Dansi *et al.*, (2013b). Cultivars perceived by farmers as tolerant to dry rot were also recorded. To assess their value and availability in the market, the six (6) most important yam markets of Benin (Dantokpa, Bohicon, Glazoué, Djougou, Parakou and Bembèrèkè) were selected and surveyed.

Morphological characterization of the cultivars tolerant to nematodes

The tubers of the cultivars perceived as tolerant to *S. bradys* by the farmers were collected in the different villages where they were mentioned and planted in a completely randomized block design with three repetitions at the experimental farm of Faculty of Science and Technology of Dassa in central Benin. Distance between lines and mounds within lines was set at 2 m to avoid stems mixing according to Loko *et al.* (2015). Morphological parameters considered (Table 1) are among those recommended in the yam descriptors by IPGRI / IITA (1997) as the most relevant for the identification and description of cultivated yams in West Africa. They are related to the details of the young stem, adult stem, young leaf, adult leaf and tubers at harvest (Loko *et al.*, 2015). Quantitative parameters were avoided because of their variability with the environment. Aerial parameters were recorded during the vegetative phase and tuber details after harvest.

Data analysis

Excel work package was used to construct histograms. Means and rates were generated through descriptive statistics using Minitab software version 17. To estimate the diversity between each diversity zones, Shannon-Wiener index (H), was calculated following Loko *et al.* (2013a) and using the formula:

$$H = -\sum_{i=1}^{s} (\frac{ni}{N}) \log(\frac{ni}{N})$$

With s, the total number of surveyed villages; ni, the number of cultivars recorded in village i and N, the total number of cultivars recorded in the study area.

To appreciate the distribution of the cultivars in the yams diversity zone, the Pielou Equitability Index (J) was calculated using the formula:

J= H/Hmax, with Hmax= log S (S= total number of cultivars in an area)

To compare the mean numbers of yam cultivars recorded in the villages and between the different diversity zones, an ANOVA (Analysis of variance) test followed by the SNK test for the means discrimination at the 5% threshold were done with R software, version 3.4. To assess the degree of similarity between the tolerant cultivars, all the collected qualitative traits were coded according to the yam descriptor used (Table 1). Thus, these cultivars were considered as individuals and qualitative traits as variables for the construction of a complete disjunctive array that was used to develop a matrix of similarity with NTSYS-pc 2.2 software (Swofford and Olsen, 1990; Rohlf, 2000). This similarity matrix was then used to construct a dendrogram using the Unweighted Pair-Group Method with Arithmetic Average (UPGMA).

Results and Discussion

Yam (*D. cayenensis-D. rotundata* complex) cultivar diversity and its evolution in the study area

Subject to synonymy and homonymy, 640 yam cultivars were recorded in the 42 surveyed villages. The number of cultivars recorded varied from 4 to 39 with an average of 22 cultivars per village (Table 2). The highest mean (28.40 cultivars per village) was recorded in the Bariba zone and the lowest (14.20 cultivars per village) in the Atacora zone. A highly significant difference (p= 0.00124) was noted between diversity zone. The Shannon Diversity Index and the Pielou's Equitability Index were 5.28 bits and 0.53 bits respectively.

D. cayenensis- D. rotundata complex is known to contain both single-harvest and double-harvest cultivars (Figure 2). In the study area, apart from the diversity zone Donga, double-harvest cultivars were the most produced in all other diversity zones and especially in Bariba area where at least 15 cultivars on average were noted per village. The analysis of variance revealed a high significant difference ($p<0.00$) between the average number of single-harvest cultivars per village in the different diversity zones. The highest average number of single-harvest cultivars (13 cultivars) was observed in the Donga zone. However, this average number was not significantly different from the one recorded in Bariba zone. This same trend was noted in the Center-South and Atacora zones where less than 5 single-harvest cultivars were produced on average per village.

In 2011, yam diversity has been already studied in 31villages out of the 42 villages surveyed and a drastic reduction of this diversity was predicted for 2016-2018. The comparison between the diversity actually recorded and the previous data (Table 3) show that in all of the diversity zones except Atacora zone, the expected averages of cultivars for 2016 were significantly lower than the one really observed in 2016. In the Bariba zone, a highly significant difference ($p<0.01$) was noted between the average cultivars obtained in 2016 and the average cultivars recorded in 2011. However, in the all other remaining diversity zones, these different cultivar averages recorded in 2016 were not significantly different from those of cultivars recorded in 2011. However, in the majority of villages except those of Atacora zone where the opposite situation was noted, the total number of cultivars obtained in 2016 was lower than the number of cultivars recorded in 2011.

Of the 22 cultivars produced on average per village, seven (7) on average (nearly 35%) were scarce cultivars (produced by few households and on small areas) compared to an average of 14 cultivars (or 65.06%) which were popular (produced by many households and over large areas, produced by many households and on small areas and produced by few households and over large areas) (Table 3).

Diversity and market value of the cultivars perceived as tolerant/resistant to *S. bradys*

According to farmers, 10 cultivars had some resistance/tolerance to *S. bradys*' dry rot disease. On average, these cultivars represent just 1% of the cultivars produced in the study area and were cited in only seven (7) of the 42 villages surveyed with more than 70% in the Center-South zone, less than 15% in each of Donga and Atacora zones and none in Bariba zone (Table 3).

The distribution and extent of these cultivars varied from one village to another in the study area (Table 4). Although 90% of these cultivars are popular, none of them are widely distributed through villages in the study area. Subject to synonymy, apart from Alakitcha and Kablitona cultivars which were widespread in two (2) villages, each of the eight (8) remaining were registered in only one village. Thus, the Alakitcha cultivar, which is cultivated by many households and on small areas in Ouôghi, is cultivated by a few households and on large areas in Ewè. Also, Kablitona which is cultivated by a few households and on large areas in Bètèkoukou, is cultivated by many households and on large areas in Gobé (Table 4). In terms of precocity, the majority of these cultivars (70%) are double-harvest compared to 30% single-harvest.

Furthermore, none of the cultivars reported by farmers as being tolerant/resistant to dry rot disease caused by *S. bradys* has market value and was not encountered in any of the six major surveyed yam trading markets.

Morphological variability within cultivars perceived as tolerant to *S. bradys*

Based on the qualitative variables considered, significant morphological variability was noted within the 10 yams cultivars perceived by farmers as tolerant/resistant to *S. bradys*.

This variability was observed not onlyat the stem of these cultivars, but also in their leaves and tubers. At the leaf level, these cultivars differ essentially from each other in leaf shape, leaf length, and lobe orientation (Figure 4a). Regarding leaf shape, more elongated shape (40%) than intermediate (30%) and cordiform (30%) forms were observed. Regarding the relative length of these leaves, the majority of cultivars had long leaves (50% cultivars) and medium (40% cultivars) while only the Sowoubanouga cultivar had short leaves. In terms of lobe orientation, 50% of the cultivars had a straight lobe. Considering the stem, more variability was observed in adult stem coloration, stem thorniness and spot at the thorn's base (Figure 4b). The adult stem of the vast majority of cultivars (80%) has green coloration. With regard to stem thorniness, 70% of the cultivars in characterization presented a very thorny stem. Similarly, 70% of them do not have a spot at the thorn's base while for 20%, a large spot was observed. Considering inflorescence, all cultivars are flowering with 50% of male inflorescence and 50% of female inflorescence cultivars. At the tuber level, corollary root's thorniness, skin colour and tuber height were the qualitative traits that showed sufficient variability (Figure 4c). Tubers are either long (50% of cultivars), medium (10% of cultivars) or short (40% of cultivars).

Classification of cultivars perceived as tolerant/resistant to *S. bradys* and morphotypes identification

The UPGMA classification generated a dendrogram (Figure 3) that individualizes each of the 10 cultivars into distinct morphotypes. At 73% similarity, there is a classification of these 10 cultivars in seven (7) groups (G1, G2, G3, G4, G5, G6 and G7) whose main distinguishing characteristics are:

Group 1 (G1): It is consisted of a single cultivar (Magbanantini) with a clear, pruinescent, smooth, and very thorny adult stem with purple thorns, large and long with a thick, long, wavy spot at the base (Figure 5a).

Group 2 (G2): It contains a single cultivar (Kpèhikpèhi) which is essentially characterized by an adult purple green, pruinescent, and very thorny stem with asperities and longitudinal striations on its lower half. Purple and curved stems downward with a large spot of the same coloration at the base.

Group 3 (G3): It is made of only the cultivar Sowoubanouga which is characterized by a green adult stem, thorny, pruinescent and rough at the base. Its thorns and spots are of the same coloration as the stem (Figure 5b).

Group 4 (G4): It contains only the cultivar Ogoudou whose young leaf has a green coloration contrary to all other cultivars for which, young leaves have purple green coloration.

Group 5 (G5): It gathers two (2) cultivars (Egnifoun and Nouonlai) that are distinguished by long, elongated leaves (Figure 5c) and little thorn corollary roots.

Group 6 (G6): It gathers three (3) cultivars (Kablitona, Yinfôkpado and Adjouayèré) having medium-length leaves with relatively short lobes and curved inward, stems with a lot of green thorns.

Group 7 (G7): It contains only the cultivar Alakitcha, which is characterized by its cordiform leaves and are arch-shaped and yellow-flesh tubers (Figure 5d).

Table.1 Qualitative morphological traits used in the characterization of yams perceived as tolerants to *S. bradys*

Parameters	Description and Coding
Leaf	
Colour of young leaves	1- Green; 3-Violet ; 5-Purple
Relative lobe length	1-Very short; 3-Short ; 5-Long
Lobe orientation	1-Straight ; 3-Curved outward; 5-Curved inward
Coloration of adult leaf	1-Green ; 3-Dark green; 5- Green blue
Leaf shape	1- Lengthened ; 3-Cordiform ; 5-Intermediate
Relative length of leaves	1-Short ; 3-Medium ; 5-Long
Inflorescence	
Flowering	1-Yes ; 3-No
Sex	1-Male ; 3-Female ; 5-No flower
Stem	
Colour of young stem	1-Green ; 3-Purple ; 5-Violet
Pruinescence	1-Absence of pruinesence; 3-Presence of pruinescence
Colour of adult stem	1-Vert ; 3- Green marbled with black; 5-Green blue; 7- Green purple
Thorniness of the stem	1-Inerm ; 3-Little thorny; 5-Very thorny
Relative length of thorns	1-Short ; 2-Medium ; 3-Long
Colour of the thorns	1-Green ; 3-Purple ; 5-Violet
Spot at the thorn's base	1-No spot; 3-Small spot; 5-Large spot
Stem roughness	1-Smooth ; 3-fully rough
Stem internodes relative length	1-Short ; 3-Medium ; 5-Long
Tuber	
Thorniness of corollary roots	1-Inerm; 3-Little thorny; 5-Very thorny
Tuber's skin colour	1-Grey skin; 3-Black spotted skin; 5-Black skin; 7-Yellow Skin
Particular structure of the skin	1-None ; 3-finely striped; 5-Presence of hexagonal figures
Skin roughness	1-Smooth skin; 3-Rough skin
Colour of the tuber flesh	1-White ; 3-Yellow white; 5-Yellow ; 7-Red Spotted White
Tuber height	1-Long ; 3-Medium ; 5-Short
Tuber size	1-Big ; 3-Medium ; 5-Small

Table.2 Variations in diversity parameters and their distribution across the study area

Diversity Zones	Number of villages	Average number of cultivars	Min	Max	Shannon H index (bits)	Pielou J index
Atacora	5	14,20 ± 3,15**c**	8	26	2,19	0,37
Bariba	15	28,40 ± 1,68**a**	16	39	3,87	0,44
Donga	6	23.66 2.24ab	16	31	2,55	0,37
South-Central	16	19.06 2.18bc	4	38	3,85	0,47
Study Area	**42**	**22,47±8,77**	**4**	**39**	**5,28**	**0,53**

Averages per column followed by the same letter are not significantly different at the 5% threshold, following SNK test

Table.3 Evolution of the diversity of *D. cayenensis-D. rotundata* from 2011 to 2017 and relative importance of cultivars perceived as tolerant to *S. bradys*

Diversity Zones	Villages	TNC recorded in 2011	TNC expected in 2016	TNC obtained in 2016	popular TNC	TNC rare	Number of cultivars tolerant/resistant to *S. bradys*	Relative frequency (%)
Center-South	Woghi*	33	18	26	14	12	1	3.85
	Gobe*	22	18	17	12	5	1	5.88
	Forget*	13	11	16	9	7	0	0
	Bètèkoukou	-	-	8	7	1	0	0
	Afinzoungo*	21	13	29	17	12	2	6.90
	Gomè	-	-	10	3	7	0	0
	Kanahoun*	32	19	25	7	18	0	0
	Djalloukou*	33	20	27	24	3	0	0
	Banon*	25	17	38	18	20	0	0
	Okoutaossé*	20	12	18	13	5	0	0
	Ikèmon	-	-	21	10	11	1	4.76
	Gbédé*	29	18	23	15	8	0	0
	Gbadagba*	9	8	12	9	3	0	0
	Koutagba*	8	6	17	10	7	0	0
	Ewè	-	-	14	8	6	2	14.29

	Bolorunfè	-	-	4	4	0	0	0
Average Center-South zone		22.27a	14.54b	22.54a / **19.06bc**	11.25b	7.81a	0.44	2.23
Bariba (Northeast)	Zougou- Pantrossi*	34	21	30	14	16	0	0
	Koutakourkou*	12	8	16	9	7	0	0
	Goro	-	-	21	20	1	0	0
	Kpari	-	-	32	22	10	0	0
	Bakpérou*	39	34	22	19	3	0	0
	Guinagourou*	43	33	38	21	17	0	0
	Kassakpéré*	35	17	33	24	9	0	0
	Bouka*	42	22	32	28	4	0	0
	Ouanrarou*	32	24	33	29	4	0	0
	Wari*	40	24	25	18	7	0	0
	Gorgoba	-	-	24	8	16	0	0
	Kabaré*	38	13	31	22	9	0	0
	Wassa-Maro	-	-	27	26	1	0	0
	Borogouru*	35	20	39	31	8	0	0
	Bipotoko	-	-	23	15	8	0	0
Average Bariba zone		35a	21.6b	29.9a / **28.4a**	20.4a	8a	0.00	0
Donga (South-West)	Igbomakro*	20	14	23	15	8	0	0
	Bodi*	22	11	21	13	8	2	9.52
	Karhum*	30	11	31	17	14	0	0
	Dendougou*	46	26	29	13	16	0	0
	Danogou	-	-	16	11	5	0	0
	Awanla*	29	10	22	16	6	0	0
Average Donga zone		29.4a	14.4b	25.2a / **23.66ab**	14.16b	9.5a	0.33	1.58
Atacora (Far Northwest)	Tchakalakou*	26	17	26	12	14	0	0
	Tantéga*	7	7	8	8	0	1	12.5
	Biacou*	7	6	15	8	7	0	0
	Kountori*	5	5	11	6	5	0	0
	Kougnangou*	9	7	11	9	2	0	0
Average Atacora zone		10.8a	8.4a	14.2a / **14.2c**	8.6b	5.6a	0.20	2.50
Study area average				**22.47**	**14.62**	**7.85**	**0.23**	**1.37**

In the TNC column (total number of cultivars) obtained in 2016, the means that are not in bold are those of the 31 villages that had already been surveyed in 2011 (affected by *) and those in bold, for all 42 villages in the study area.

Table.4 Distribution, extent and precocity of cultivars perceived as tolerant/resistant to *S. bradys* by farmers

N◦	Cultivars perceived as tolerant/resistant to *S. bradys*	Distribution and extent	Precocity
1	Alakitcha	Ouôghi (M+S-), Ewè (M-S+)	Single-harvest
2	Kablitona	Bètkou (M-S+), gobé (M+S+)	Double-harvest
3	Yinfôkpado	Afinzoungo (M+S+)	Double-harvest
4	Sowoubanouga	Afinzoungo (M+S-)	Single-harvest
5	Egnifoun	Ikèmon (M+S+)	Double-harvest
6	Kpèhikpèhi	Ewè (M-S+)	Double-harvest
7	Ogoudou	Ewè (M-S-)	Single-harvest
8	Adjouayèré	Bodi (M+S+)	Double-harvest
9	Magbanantini	Bodi (M+S+)	Double-harvest
10	Nouonlaï	Tantéga (M+S+)	Double-harvest

Popular cultivars (M+S+, M+S-, M-S+) and scarce cultivars (M-S-)

Figure.1 Map of Benin showing villages surveyed

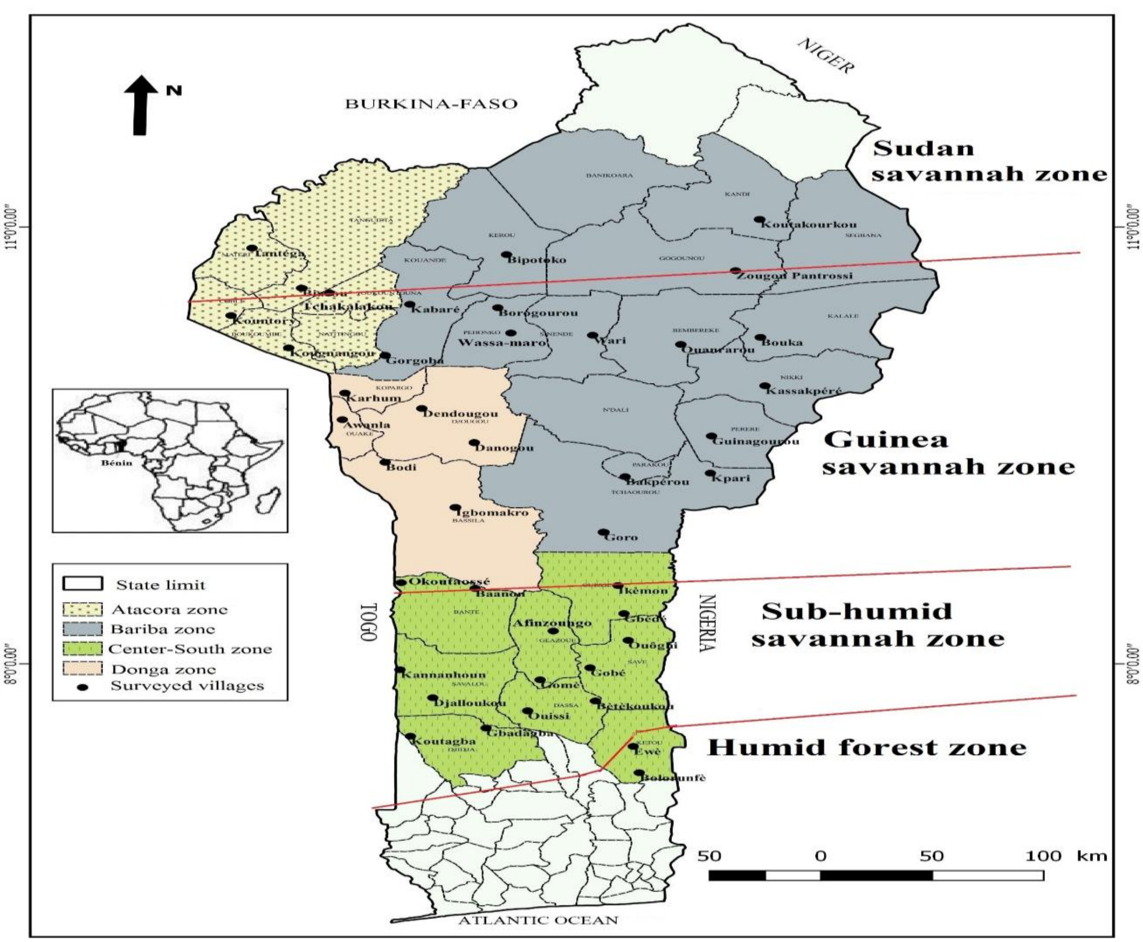
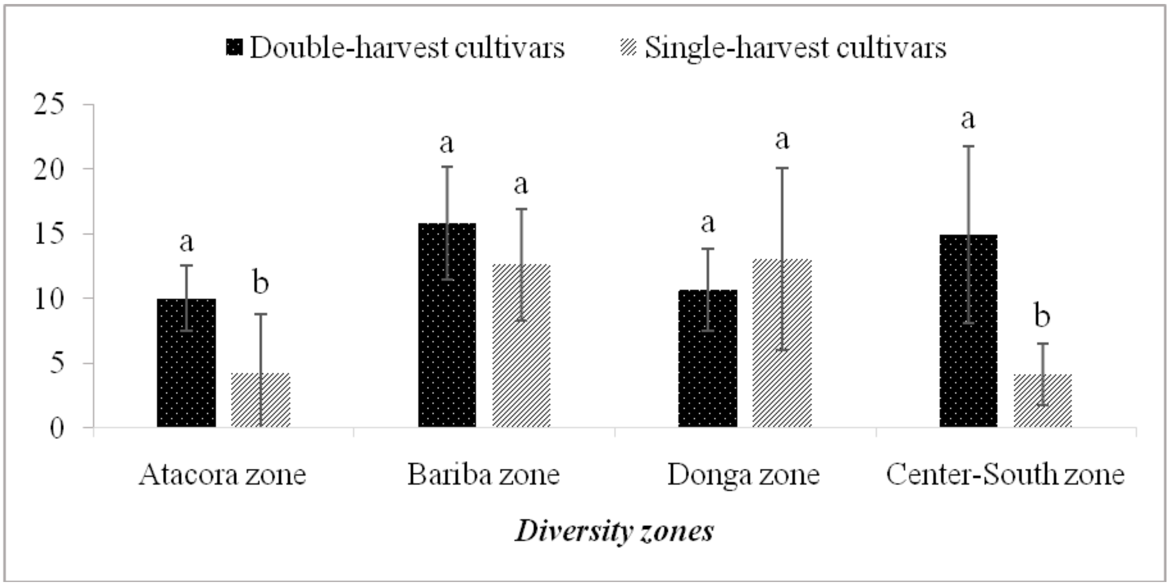


Figure.2 Diversity by vegetative cycle in the *D. cayenensis-D. rotundata* complex in the study area



Average numbers assigned from the same letter within a variable are not significantly different at the 5% threshold

Figure.3 UPGMA Dendrogram showing similarity of 10 cultivars perceived as resistant/tolerant to *S. bradys* based on morphological descriptors

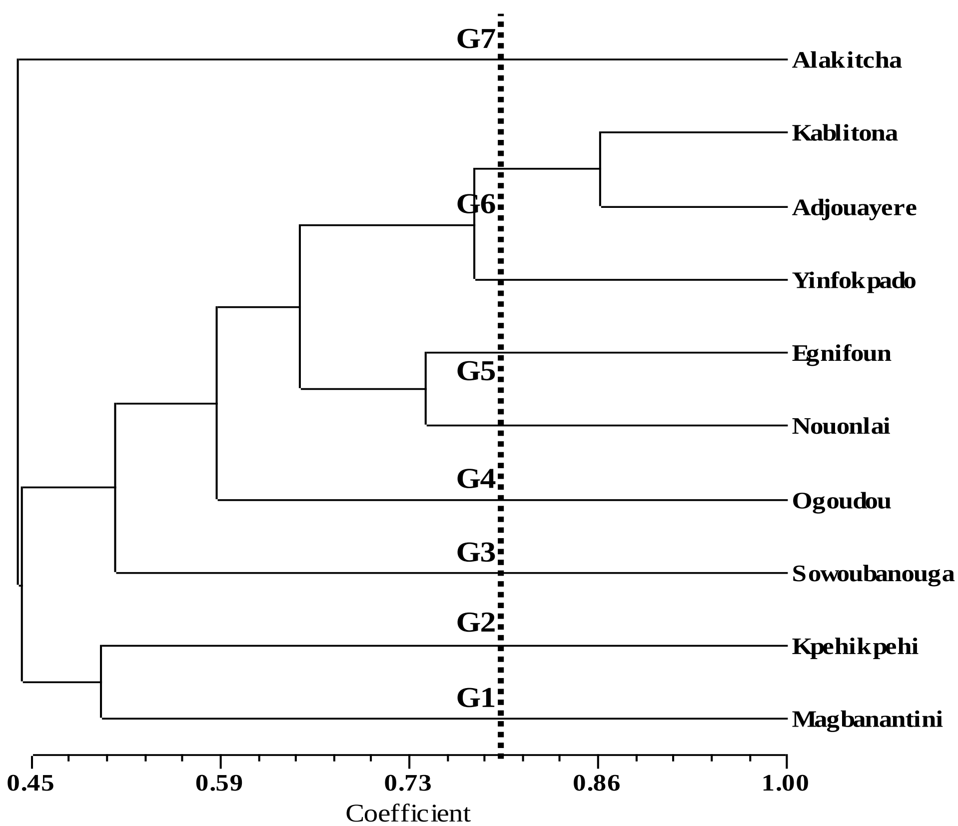


Figure.4 Frequency of some morphological traits in the leaves, stem and tubers of cultivars perceived by farmers as resistant/tolerant to *S. bradys*

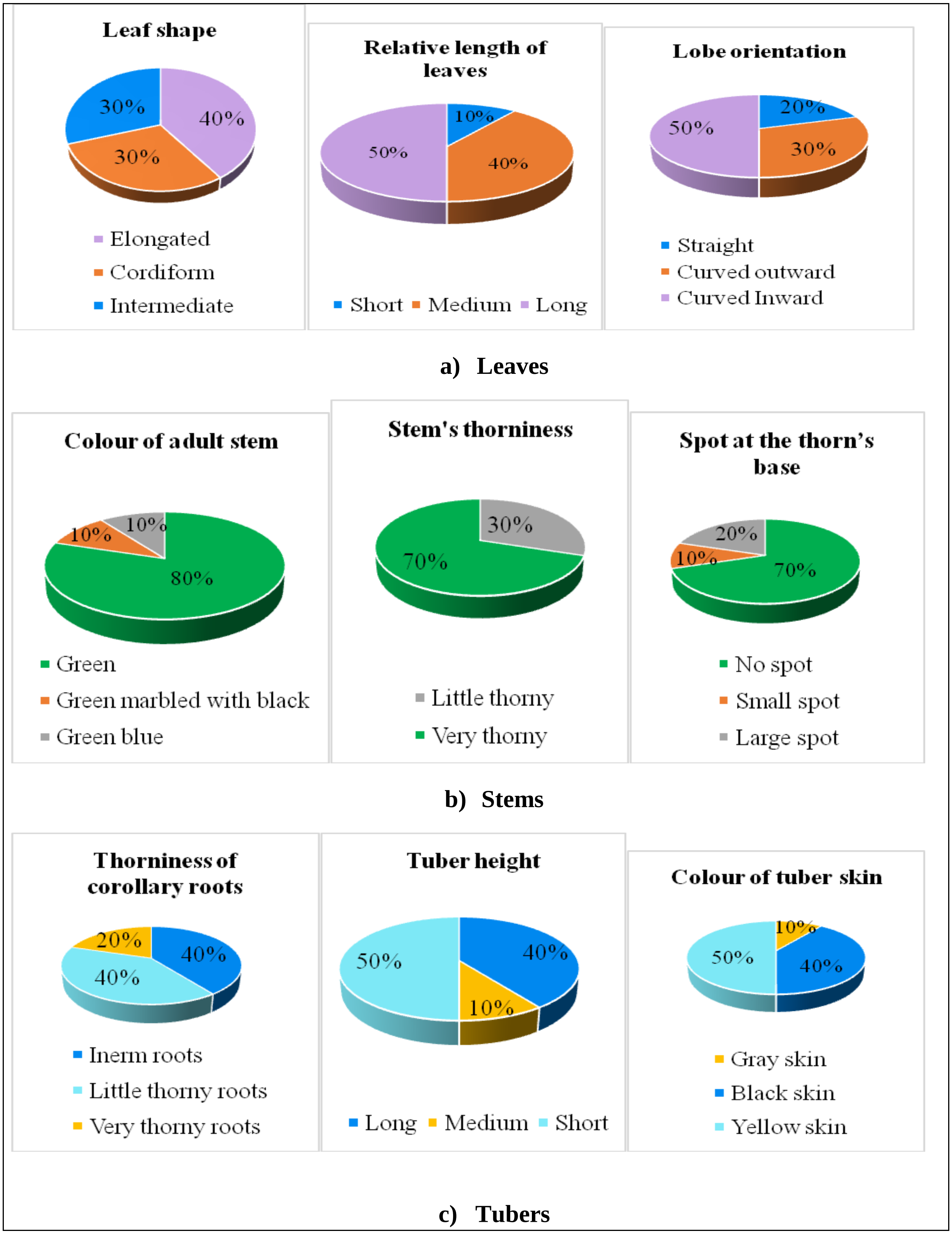


Figure.5 Variability of leaves, stems and tubers in some yams cultivars perceived by farmers as resistant/tolerant to *S. bradys*

a) Cordiform leaves and yellow flesh (Alakitcha)

b) Thorny adult stem, pruinescent and rough (Sowoubanouga)

c) Elongated long leaves (Nouonlai)

d) Large spot at the thorn's basis (Magbanantini)

The yams of the *Dioscorea cayenensis-D. rotundata* complex are the most important, the most cultivated and the most consumed by both producers and consumers in West Africa (Mignouna and Dansi, 2003).

Subject to synonymy, the results of the current study showed the existence of a diversity of 640 cultivars with a Shannon bit diversity index of 5.28 and a Pielou equitability index of 0.53; indicating that the study area is highly diversified and that different cultivars are unevenly distributed. These results support the findings of Dansi *et al.,* (2013b) that the *D. rotundata-D. cayenensis* igname diversity center is West Africa.

The results also revealed that the highest average (28.40) and the lowest (19.06) of cultivars were recorded in the Bariba and Atacora zones, respectively. The peculiarity of the Bariba zone's farmers to always have a wide diversity of yam cultivars has already been reported by Dansi (2000). As Atacora zone is heavily affected by drought (Houndénou and Hernandez, 1998), the low diversity observed compared to other zones would be due to the requirements that cultivars must have to cope with climatic and edaphic constraints of this environment (Loko *et al*., 2013b).

Depending on the vegetative cycle's duration, double-harvest cultivars were the most widely grown except in the Donga zone where single-harvest cultivars predominated. In Benin, fresh yams tubers processing into ships for local markets is the inherent property of this zone's people who have the best techniques and the most required cultivars to obtain the best quality of ships are the Kokoro (single-harvest cultivars) (Dansi *et al.,* 1999). This justifies the single-harvest cultivars preponderance in the Donga zone.

The results of the comparative study of the 2011 diversity to the one predicted for 2016 and the one really obtained showed that in all of the diversity zone except Bariba zone, no significant difference was noted between the averages cultivars recorded in 2011 and those obtained in 2016, which were, however, significantly different from the expected average "cultivars for 2016. These results reveal that from 2011 to 2016 (5 years), the predicted extinction of all endangered cultivars was not effective. Indeed, some cultivars almost never change their status because they have neither agronomic performance nor market value, but have values in other areas such as medicinal or worship plan. This causes some producers to always maintain them in a few mounds in the field. Thus, these cultivars are still threatened with extinction without being able to disappear. This is the case, for example, of the cultivar "*Guirissi Wonka*", which is used only to protect fields against bad minds. Although there was no significant difference in the number of cultivars recorded in 2011 and 2016, the total number of cultivars recorded in 2016 was lower than the one recorded in 2011 in more than half of the villages. This nonetheless demonstrates a gradual reduction in diversity that could become significant if the appropriate conservation measures are not taken.

According to farmers, ten cultivars were resistant/tolerant to dry rot disease caused by *S. bradys.* These results are similar to those of Loko *et al.,* (2013b) who reported the existence of such cultivars and that a participatory evaluation of existing cultivars could help to identify more for their use in breeding programs or directly by farmers through varietal exchange. On average, however, these cultivars account for just 1% of the cultivars produced in the study area, with the majority (over 70%) concentrated in the Center-South zone and none in the Bariba zone (very high yam diversity area in Benin). These results clearly indicate that none of these cultivars are widely distributed and should be preserved *in situ (*Jarvis *et al*., 2000; Dansi *et al*., 2010) for confirmation tests.

Furthermore, none of these cultivars have a market value. The possibility that nematode-tolerant/resistant cultivars lack culinary characteristics and hence market values has already been reported by Starr *et al.* (2002). The primary objective of a producer is to produce what is in high demand in the market in order to make profit and an improvement or selection program that occult the market value of the harvested products would be futile. It is therefore urgent that screening tests to confirm the resistance of these cultivars perceived as resistant/tolerant be extended to those with high market value in order to determine their level of susceptibility to *S. bradys* attacks to allow plant breeders to be able to undertake crossbreeding opportunities that will lead to new cultivars that are not only resistant but also have high market value.

In terms of vegetative cycle duration, the majority of these cultivars (70%) are double-harvest. Indeed, for most crops, precocity is one of the most sought-after economic criteria by producers and breeders (Essono *et al*., 2008; Acheampong *et al*., 2013; Robooni *et al*., 2014). Especially in the Benin context where climate variability is already noticeable (Gnanglè *et al.,* 2011; Loko *et al.,* 2013a), precocity becomes a farmers adaptation strategy (Tidjani and Akponikpe, 2012; Agbossou *et al.,* 2012) because they are guaranteed that before the early cessation of rainfall, production would be more or less significant and that crops would already be expected to be under good auspices to meet their food and economic needs.

In order to study the genetic variability within these 10 cultivars perceived as resistant/tolerant to dry rot caused by *S. bradys*, a morphological characterization was made as this is the first requisite step in the description of genetic resources (Radhouane, 2004). It was essentially based on qualitative traits because of their importance to the plants description (Nadjiam *et al*., 2016). Current study showed significant morphological variability within these yams cultivars which were individualized into distinct morphotypes according to UPGMA classification. Morphologies reflecting not only the cultivar genetic make-up, but also the interaction of its genotype with the environment in which it was expressed (Smith and Smith, 1992), these morphological markers are therefore influenced by the environment (Li *et al*., 2015). Molecular markers that cannot be influenced by environmental factors may help to confirm or not these results.

The results also showed that these cultivars are all flowering. Since flowering and fruition difficulties have always been the major constraints of genetic improvement in yams in the *D. cayenensis –D. rotundata* complex (Hamadina *et al.*, 2009), these cultivars can therefore easily be involved in breeding programs by breeders, if they are confirmed resistant/tolerant by screening tests.

But until these tests are done on these cultivars and those with high market value, farmers' awareness on existing control methods such as the use of healthy planting materials and weeding to control the potential host population is critical (Bridge and Starr, 2007). For the significant reduction of large populations of *S. bradys* in tubers, the cover plant *Mucuna pruriens* was advised (Claudius-Cole *et al.,* 2004). In the crop rotation system, peanuts were recommended for the reduction of low *S. bradys* populations and the restoration of soil fertility prior to the installation of a new yam field (Atu and Ogbuji, 1983). *Cajanus cajan* can also be used as a *S. bradys* trap plant because it supports its initial penetration but impedes reproduction (Claudius-Cole and Fawole, 2016). With regard to crop association, bean, rash, okra, tomato, melon and any host plant should be avoided (Bridge *et al*., 2005).

In conclusion, this study confirmed that Benin has an important diversity of yam from (*D. cayenensis-D. rotundata* complex) cultivars unevenly distributed throughout the country. Over a five-year period, there was no significant reduction in the total number of cultivars per village. Of the 22 cultivars produced on average per village, only 1% are perceived as resistant/tolerant to *S. bradys* and have no market value with significant morphological variability. Thus, there is a need to extend the screening tests of these cultivars perceived as tolerant to dry rot, to those with high market value for their resistance level assessment for breeding prospects.

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