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RESEARCH ARTICLE

Ethnobotany, landraces diversity and potential vitamin A rich cultivars of sweet potato (*Ipomoea batatas* (L.] Lam.) in southern and central Benin

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Abstract Sweet potato is an important staple food in Benin, which unfortunately remains neglected by research and underutilized. To document the diversity of the crops for its sustainable conservation and use, an ethnobotanical investigation was conducted in 34 villages selected in Central and Southern Benin using participatory research approach methods and tools. For 24.59 % of the respondents, sweet potato is ranked as the sixth most important crop produced. 19.36 % of the respondents produced sweet potato for feeding purpose only, while 46.77 % of respondents are growing it for purely economic purposes. At total 12 constraints related to the sweet potato production were registered through the study area, among which eight, which represent 66.67 % of the constraints could be solve by the scientific research efforts while the rest (four constraints, 33.33 %) were purely of political order. The difficulty of farming practices (20.39 % of responses) and the sensitivity of the crop to the attack of pests and insects (19.74 % of responses) appeared as the major constraints cited by the respondents. The numbers of sweet potato varieties per village range from 2 (two) to 11 (eleven) with an average of 5 varieties per village. The Shannon diversity index of the South (4.06) is greater than the one of the Centre (4.00) and shows that South region has a relatively highest range of varieties and so suitable for the crops diversity conservation. At 65 % of similarity, the cluster analysis using UPGMA dendrogram classified the 108 sweet potato cultivars identified in eight groups corresponding to 92 morphological units based on 13 agronomic traits and culinary characteristic. Within the varietal group, it denotes some yellow (27.45 %) and orange (3.92 %) flesh variety groups of sweet potato which constitute potential source of vitamin A. The study of the vitamin A (caroten) content of those varieties is to be considered to fully exploit their nutritional potential.

Keywords Benin · Diversity · Food security · *Ipomea batatas* · Sweet potato · Vitamin A

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Introduction

Root and tuber crops play an important role among edible plants worldwide. They rank third after cereals and grain legumes and are the staple food for over 20 % of the world population (FAOSTAT 2010).

Among the cultivated root and tuber crops in the world, sweet potato (*Ipomoea batatas* (L.) Lam.) is one of the economically most important (Huang et al. 2013; Iheagbaria et al. 2013). However it is still among the most under-exploited species of the developing world's major crops (Tomlins et al. 2012). Sweet potato is less labor intensive than most other staple crops and can be planted over a broad range of time without considerable yield loss (Low et al. 2007). It is grown widely around the world and ranks fifth as a food crop in developing countries after rice, wheat, maize and cassava (Huang et al. 2013). In Benin sweet potato is produced and consumed (boiled or fried) mainly in the southern part of the country (Sanoussi et al. 2013). In 2013, the country's total production was estimated at 64,860 tons (FAOSTAT 2014).

For this crop, both leaves and roots are useful for human and animals foods. According to Huang et al. (2013), the leaves of the sweet potato contain many nutrients including protein, dietary fiber, carotenoids, and vitamins and could be harvested several times per year and their harvest is never worse than that of ordinary leafy vegetables. The sweet potato root is used both as food and as material for the production of beverages, pasta, alcohol drink, and natural colorants (Steed and Truong 2008, Huang et al. 2013). Its starch has been widely used in starch noodles, bakery foods, snack foods and confectionary products (Iheagwara et al. 2013). Sweet potato contains several types of beneficial and functional pigments, such as flavones, β-carotene and anthocyanins for deep yellow, orange, and purple-fleshed sweet potatoes, respectively (Truong et al. 2007).

In the traditional agroecosystems in Africa and elsewhere, farmers generally grow a large diversity of landraces per crop species that need to be conserved as its sustainable utilisation may help to lower the risk of crop failure owing to vagaries of climate, diseases, pests and soil limitations (Duputie et al. 2009; Gbaguidi et al. 2013). Locally adapted landraces usually produce lower yields during optimal conditions than ''improved'' cultivars, but the relative stability of their yields provides food security to households (Yongan et al. 2010; He et al. 2011).

In Benin, sweet potato production is reported as constrained by several biotic and abiotic factors and the lack of improved high yielding cultivar (Sanoussi et al. 2013). Several cultivars do exist in the traditional agriculture with possible varying levels of agronomic traits such as high yield of storage organ, high dry matter (DM) content, vigorous foliage development (Tairo et al. 2008). Unfortunately and contrary to other crops such as yam (Loko et al. 2013) and sorghum (Dossou-Aminon et al. 2014) there only few ethnobotanical data available in the literature on sweet potato diversity, production and utilization for use by scientific research and development.

The consumption of vitamin A-rich sweet potato helps preventing vitamin A deficiency (Tomlins et al. 2012). It is therefore important to develop or identify within the existing diversity, such cultivars for promotion. Today, the development of modern and well adapted cultivars of sweet potato that could meet the needs of both farmers and consumers becomes an imperious challenge (Frison et al. 2011; Mulumbaa et al. 2012). The knowledge of existing landraces and farmers' selection criteria are a prerequisite to designing a concrete breeding programme and to hope that the improved cultivars will be adopted (Luka and Yahaya 2012; Sesay et al. 2013; Dossou-Aminon et al. 2014).

To preserve the existing landraces against genetic erosion, germplasm collection and conservation ex situ is a necessity (Dansi et al. 2010; Zawedde et al. 2014). However, for the landraces to evolve and be continuously adapted to their environment, complementary on-farm conservation strategies should be also developed (Dossou-Aminon et al. 2014). To do this, the status of the diversity of the crop and the traditional seed system as well as the on farm seed maintenance should be well understood. For sweet potato in Benin, there is dearth of information on such data.

We report in this paper the results of an ethnobotanical survey conducted in the sweet potato production zones in southern and central Benin in order to:

- Understand the constraints of sweet potato production in Benin as well as the traditional seed system and on farm seed maintenance
- Assess the diversity, performance and farmers' preference or selection criteria of sweet potato cultivars at both community and household levels
- Identify, within the existing diversity, the potential vitamin A-rich cultivars and the level of farmer knowledge with regard to these varieties
- Collect germplasm for ex situ conservation and utilisation

Materials and methods

Study area and site selection

The Republic of Benin is situated in West Africa and between the latitudes 6°100 N and 12°250 N and longitudes 0°450 E and 3°550 E (Akouègninou et al. 2006). It covers a total land area of 112,622 km^2 with a population estimated at about 9 million (Orobiyi et al. 2013). The study was conducted in 34 villages of Southern and Central country (Fig. 1). The study area is a relatively humid agroecological zone with two rainy seasons and means annual rainfall varying from 1100 to 1400 mm/year (Akouègninou et al. 2006, Yabi and Afouda 2012). It is partitioned into eight departments (Atlantique, Littoral, Mono, Couffo, Oueme, Plateau, Zou and Collines) inhabited by 15 ethnic groups (Adja, Cotafon, Holly, Ouémègbé, Pédah, Saxwè, Tori, Watchi, Xwla, Yoruba, Idaasha, Fon, Mahi, Fè, Tchabè) differently located (Dansi et al. 2008).

In order to sufficiently cover the study area, the 34 surveyed villages were randomly selected throughout the different departments and ethnic areas. The names and the ethnic groups of the surveyed villages as well as the departments to which they belong and their geographical locations are compiled in Table 1.

Data collection

Data were collected during expeditions from the different sites through the application of participatory research appraisal tools and techniques, such as direct observation, group discussions, individual interviews, and field visits using a questionnaire following Dansi et al. (2010), Kombo et al. (2012). In each village, interviews were conducted with the help of a local translator and groups surveyed were made of 20–40 sweet potato producers of both sexes and of different ages. Producers were identified and assembled with the assistance of the local farmers' associations and the chiefs of the village involved in the study to facilitate the organization of the meetings and the collection of data (Gbaguidi et al. 2013). In each selected site, information on the location (name of district, name of village, ethnic group) was first collected after a detailed presentation of the research objectives to the farmers.

Production constraints were documented and prioritized in group by identifying and gradually eliminating the most severe, the most critical ones for which an urgent solution must be found (Kombo et al. 2012). The process was repeated until the last constraint was ranked and the results were immediately given to the producers for approval. The same participatory approach was used to identify and prioritize the preference criteria at community level (Dansi et al. 2013; Orobiyi et al. 2013). Cultivars were inventoried and their distribution and extent assessed using the Four Cell Analysis method described by Dossou-aminon et al. (2014). This participatory approach help identifying elite cultivars (produced by many households and on large surface areas) and assessing the rate of cultivar loss or abandonment if any.

The sweet potato varieties identified were evaluated on participatory way (group of farmers), using a pre-prepared agronomic and culinary evaluation sheet and the two level (appreciated–disliked) evaluation method described by Kombo et al. (2012) and Dansi et al. (2012). Parameters considered were: relative productivity, length of the cycle, tolerance to pests and diseases, tolerance to abiotic stresses (high soil moisture, drought, poor soil), soil selectivity, cooking (taste, usage of the leaves as vegetable) and organoleptic (friability, oxidation of the root after peeling, color of the flesh, coloration of the flesh after cooking) qualities, presence of vitamin A (as indicated by the flesh color).

Group discussions were followed by individual surveys conducted in two households randomly selected per village using the transect method described by Adjatin et al. (2012). In the households, interviewees were chosen following Christinck et al. (2000) and Gbaguidi et al. (2013). Information collected was related to: socio-demographic data (Age, sex, area of sweet potato field exploited, household size, labour size, and educational level), sweet potato cultivar diversity maintained by households, mode and frequency of consumptions, consumer preference criteria using the comparison matrix method (Adoukonou-Sagbadja et al. 2006).

Data analysis

Data obtained were analyzed using descriptive statistics and the results were presented in the form of

Fig. 1 Geographic localization of villages surveyed in the study area

tables or figures. At the level of study zone, the constraints were prioritized based on the average of the following three parameters according to Gbaguidi et al. (2013):

- The total number of villages (TNV) in which the constraint is cited
- The number of villages in which the constraint was classified among the principal constraints (PCO) i.e. among the first five
- The number of villages where the constraint is the major one or ranked first (MAC)

For these three parameters, the higher the number, the more important the constraint. The importance of a constraint (IMC) was determined by the formula IMC = (TNV + PCO + MAC)/3. The same approach was used to rank farmers' cultivar preference criteria.

Table 1 Geographic location and ethnic groups of villages surveyed

S/N	Village	Municipality	Department	Geographic location	Ethnics groups
1	Adjacomè	Lokossa	Mono	South	Adja
2	Aglongbé	Adjara	Ouémé	South	tori, goun
3	Agonmè	Savalou	Collines	Centre	Mahi
4	Aïta	Sakété	Plateau	South	Tori
5	Aklampa	Glazoué	Collines	Centre	fon
6	Akodéha	Comè	Mono	South	Sahouè
7	Azohè- Aliho	Tori bossito	Atlantique	South	Aizo
8	Bozoun	Abomey calavi	Atlantique	South	Aizo
9	Dasso	Ouinhi	Zou	Centre	fon
10	Dogla-Houngodo	Dangbo	Atlantique	South	Ouémin
11	Dokoui-doho	Ouèssè	Collines	Centre	Mahi
12	Ewè	Kétou	Plateau	South	fon
13	Gakpé	Ouidah	Atlantique	South	fon
14	Gbodjoko	Abomey calavi	Atlantique	South	Aizo
15	Gobé	Savè	Collines	Centre	Ditamari
16	Issaba	Pobè	Plateau	South	Holli
17	Ita-djèbou	Sakété	Plateau	South	Nagot
18	Kissamè	Djacotomey	Couffo	South	Adja
19	Kouékouékanmè	Djidja	Zou	Centre	fon
20	Koundokpoé	Zè	Atlantique	South	Aizo
21	Madjrè	Applahoué	Couffo	South	Adja
22	Mbéga	Djidja	Zou	Centre	Fon
23	Odo- agbon	Savalou	Collines	Centre	Ifè
24	Oko-akaré	Adja-ouèrè	Plateau	South	Nagot
25	Okoutaossè	Bantè	Collines	Centre	Itcha
26	Pira	Bantè	Collines	Centre	Ditamari
27	Sagon	Zagnanado	Zou	Centre	fon
28	Sèdjè	Bonou	Ouémé	South	Ouémin
29	Setto	Dassa-Zoumè	Collines	Centre	fon
30	Sissèkpa	Adjohoun	Ouémé	South	Aizo
31	Soclogbo	Dassa-Zoumè	Collines	Centre	fon
32	Toffo-aggué	Toffo	Atlantique	South	Aizo
33	Vacon	Missérété	Ouémé	South	tori
34	Zinviè	Abomey calavi	Atlantique	South	Aizo

The rate of diversity loss (RDL) at the village level was determined, according to Kombo et al. (2012), using the formula RDL = (n − k)/N × 100 where n is the number of endangered cultivars (cultivated by few households and on small areas); k is the number of cultivars newly introduced; N is the total number of cultivars identified in the village. Relationships between socio-demographic parameters (age, sex, cultivated acreage, number of labour, household size, and education level) of the households and the cultivar diversity it manages were examined through Pearson correlation analysis using Minitab 14 software (Minitab Inc., State College, PA, USA).

To study the cultivar diversity in terms of agronomic and technological performances, a dendrogram was constructed using UPGMA (Unweighted Pair-Group Method with Arithmetic Average) clustering method and NTSYS-pc 2.2 (Numerical Taxonomy and Statistical Analysis) software (Rohlf 2005) by considering identified sweet potato cultivars as

individuals and evaluation parameters as variables (scored 1 or 0) according to Kombo et al. (2012).

Results and discussion

Characteristics of the respondents and sweet potato production in the study area

A total of 68 randomly selected farmers were individually interviewed in the 34 villages surveyed. Among these 62 (91 %) were males while only 06 (9 %) were females. Like with yam (Sesay et al. 2013) and cassava (Kombo et al. 2012), sweet potato production appears in the study area to be mainly male prerogative. Most of the respondents (50 %) were illiterate and over half were between 30 and 50 years old (average of 46 years). These results are consistent with those obtained by Luka and Yahaya (2012) and Sesay et al. (2013) on yam in Nigeria and Sierra Leone and by Zawedde et al. (2014) on sweet potato in Uganda. The respondents experience in the sweet potato production varies from one) to sixty-five years with an average of fifteen years. The majority of the producers (60.9 %) are well experienced in sweet potato cultivated as they practice it since at least ten years.

The majority (68.85 %) of the respondents reported that sweet potato production ranks fourth to sixth position among the others crops throughout the study area while for 31.15 % of them the crop ranks first to third.

The results of farmers' perception of the evolution of sweet potato production across the study area (Table 2) showed an increasing production as well as in the study area (47.62 % of respondents) and in the two regions (South and Centre) considered separately. Although the evolution tendency is similar from one region to another, the increase seems to be more perceived in the central region (51.85 % of respondents) than in the Southern region.

Throughout the study area, sweet potato farmers practice mostly sole culture. Planting of cuttings is done from May to July or sometimes from August to November. This second generation of planting is mostly practiced in the regions of lowlands like Bozoun, Dangbo (Kouvè) and Issaba where water supplies ensure early germination of cuttings. Sweet potatoes are available in most of the regions from February to July. Cuttings are planted on ridges (55.55 % of respondents), mounds (33.33 % of respondents) or planks (11.11 % of respondents). Utilization of fertilizers and pesticides is very limited as only 17.19 and 7.81 % of sweet potato farmers respectively recourse to these practices. Maturity of the storage roots is indicated by the yellowing and falling of the plant leaves (52.58 % of the farmers), the cracking of the soil (44.71 % of the farmers) or flowering of the plant (4.71 % of the farmers). Throughout the study area, the size of the sweet potato cultivated lands per household varied from 25 sto 35,000 m^2 with an average of 5041.79 m^2. However, these data vary from one region to another. The average land area sown at South (7554.05 m^2) is for instance about three times larger than the one of the Central region (Table 3). Sweet potato cultivation in Benin appears therefore more concentrated in the South than in the Centre. This observation is well in convenience with the local statistics of sweet potato production in Benin. Most (46.77 %) of the farmers surveyed grow the crop for economic reasons while the others cultivate it for feeding purpose (19.35 % of farmers) or both economic and feeding purpose (33.87 % of farmers).

The production constraints reported by the produced were of various natures. At total 12 (sixteen)

Table 2 Farmers perception of evolution of sweet potato production through the study area

Evolution	Frequency (%)	South (%)	Centre (%)
Increasing	47.62	44.44	51.85
Constant	14.29	13.89	14.81
Decreasing	38.10	41.67	33.33

Table 3 Variation of sweet potato farms size throughout the study area

Regions	Size of sweet potato farms (m^2)		
	Minimum	Average	Maximum
Study area	250	5041.79	35,000
South	250	7554.05	35,000
Centre	300	2478.7	10,000

constraints were recorded (Table 4). Among these, 8 (difficult cultivation practices, climate variability, attack of pests and insects, lack of seeds, low soil fertility, poor storage capacity of the root, low productivity, soil selectivity) representing 66.67 % of the constraints could be solved by scientific research. The remaining (four in total) were purely of political order. Fulgie (2007) in targeting the priorities for sweet potato research in developing countries and Ngailo et al. (2013) in summarizing the progress of sweet potato breeding in some region of the world especially in Africa have also noted that the production of sweet potato is affected by several biotic constraints such as viral diseases, insect pests and weeds, significant abiotic constraints including low soil fertility and drought and several socio-economic constraints such as inadequate availability of high yielding, lack of disease resistant planting materials, poor or no fertilization and weeding, and lack of post-harvest technologies. So efforts must be made to find solutions to these constraints in order to increase the sweet potato production and its value chain in Benin. For these, there are some priorities to consider with regard to the importance of the constraints reported by the producers interviewed (Table 4). Among the constraints recorded, difficult cultivation practices, pest and diseases attacks, climate variability (especially drought) were the most important and ranked first, second and third respectively. This result is in agreement with Fulgie (2007), who highlighted that for sweet potato improvement, drought tolerance and virus resistance combined with earliness and high and stable yield are of high priority. Therefore, the utilization of performants varieties identified among the existing varieties or developed through the use of participatory research and genetic tools may help to face those constraints.

Diversity of sweet potato landraces in the study area

Subject to synonymies, 108 farmer-named cultivars of sweet potato were reported throughout the study area. The number of sweet potato cultivars per village ranged from 2 to 11 with an average of 5 cultivars per village (Table 4). Villages Agonmè, Aklamkpa, Dokoui-dôhô, Kissamè, Mbèga, Odo-agban and Togbin (almost located in the Centre) have the lowest number (2) of landraces while Bozoun, Dasso, Sissèkpa, Sèdjè (almost located in the South) have the highest diversity (11). The Shannon diversity index calculated was 4.88

Table 4 Constraints of sweet potato production throughout the study area

Constraints	Importance in the study area				Variability per region (% of response)		
	TNV	MAC	PCO	IMC	Study area	Centre	South
Difficulties of cultural practices	31	13	30	24.67	20.39	25.81	74.19
Attack of insects and pests	30	3	27	20.00	19.74	40.00	60.00
Climate variability (lack of rain/drought)	18	6	17	13.67	11.84	22.22	77.78
Lack of selling market	18	5	17	13.33	11.84	50.00	50.00
Lack of planting material	15	3	15	11.00	9.87	46.67	53.33
Low soil fertility	9	1	8	6.00	5.92	22.22	77.78
Poor storage capacity (low shelf life)	7	1	6	4.67	4.61	28.57	71.43
Lack of arable land	7	1	4	4.00	4.61	14.29	85.71
Low market value	6	1	5	4.00	3.95	16.67	83.33
Labour inadequacy	5	0	4	3.00	3.29	20.00	80.00
Low productivity	3	0	3	2.00	1.97	66.67	33.33
Inadaptability to all types of soil	3	0	2	1.67	1.97	33.33	66.67

TNV total number of villages in which the constraint is cited; *MAC* Number of villages where the constraint is cited as the Major (first) Constraint; *PCO* Number of villages in which the constraint was classified among the Principal Constraints (among the first five); *IMC* importance of a constraint

for the study area, 4.06 for the South and 4.00 for the Centre. The study area presents high diversity of sweet potato landraces and the southern region appeared as the richest ones.

The distribution and extent analysis of the landraces showed that out of the diversity recorded per village, only few landraces are cultivated by many households and on large surface areas (H+A+) and can be considered as elite cultivars (Table 5). Their number per village varies from one to four. Within the 108 landraces recorded and subject to synonymy, 37 (about one-third) were registered as elites cultivars. The highest numbers of elite cultivars were found at Aïta, Vacon and Zinviè which are located in the Southern part of the countries (Table 5). Among the elites cultivars, Vobodouaho, Hanmankan, Glokan, Gbôadô, Elehan akparo, Bombo 1 and Bombo 2 were recognized as such in several villages and may be considered as super elites sweet potato cultivars and may be consider as potential performant varieties to be targeted for use to face constraints in sweet potato production in Benin and for use future sweet potato improvement programme. Others cultivars such as deux-couleurs, Koïdokpon and Bomankan were mentioned as elites in only one village. The list, the maturity cycle and villages of abundance of the elite cultivars are summarized in Table 6. The analysis of distribution and extent of sweet potato diversity also allow to observe that the categorie H+A+ register a lower number of variety than the two others categories (H+A−) and (H−A−) combined. It can be deduced that the major production of sweet potato is mainly based on limited number of varieties while the majority of landraces are produced on small surface area and may be loss at any time since they are maintained by few household (H−A−).

Across villages surveyed, many cultivars were threatened. The rate of diversity loss (RDL) (Table 5) varied from 25 to 100 % (57.35 % in average). Villages Aglongbè, Togbin (Toffo-Agué) and Soclogbo located in South and Centre respectively recorded the highest rate of diversity loss. Such high diversity loss rates were reported on cowpea (Gbaguidi et al. 2013), sorghum (Dossou-Aminon et al. 2014), yam (Loko et al. 2013, Dansi et al. 2013) and cassava (Agre et al. 2015) and indicate the necessity of developing strategies for safeguarding the existing genetic diversity for both present and future generations. Zawedde et al. (2014) in Uganda reported that the high landraces diversity loss rates may be explained by the agricultural intensification leading to the displacement of farmer's local varieties by few improved cultivars. In Benin, no sweet potato improvement program exists. Therefore cause of cultivars loss should be other. According to the producers, 16 reasons justify diversity loss in sweet potato in Benin (Table 7). Among them, the most important were low productivity (21.17 % of responses), lack of planting material (15.65 % of responses), inadaptability to all type of soil (12.24 % of responses) and long maturity cycle (10.20 % of responses). This result is consistent with the observations of Zawedde et al. (2014) who mentioned that yield stability, tolerance to native biotic and abiotic stress and good taste were important for maintenance of currently grown sweet potato cultivars in Uganda.

The number of landraces maintained per households varied from 1 to 9 with two on average. Households cultivating only one cultivar represent 27.14 % while those having two or three to five cultivars were respectively 41.43 and 27.14 % of the households (Fig. 2). In term of genetic resources conservation, there is need of collection of the existing diversity and establish a proper field for on farm management program in at least two village per region by associating at least 05 households in the in order to prevent an eventual genetic erosion.

Folk nomenclature and taxonomy

Nine vernacular names of sweet potato were recorded across the twelve ethnics groups surveyed in the study area. The analysis of the meanings of vernacular name confirms the existence of various scenarios (unexplained names, synonymy, and same name across ethnic area) which are specific to folk nomenclature as reported by Mekbib (2007), on Sorghum, Dansi et al. (2010), on fonio, and Assogba et al. (2015) on Kersting's groundnut. The meanings of the vernacular names, as reported by farmers, reflected some morphological, agronomic, culinary performances of the plant. Similar results were reported on yam (Loko et al. 2013), sorghum (Dossou-Aminon et al. 2014) and Kersting's groundnut (Assogba et al. 2015) in Benin.

To identify on farm sweet potato varieties within the existing diversity, farmers use 12 morphological traits related to different organs of the plant

Table 5 Diversity, distribution and extent of the sweet potato landraces in the study area

S/N	Village	TNL	Distribution and extent			NIL	NTL	RDL (%)
			NEL (H+A+)	H+A−	NRL (H−A−)			
1	Adjacomè	4	1	0	3	0	3	75.00
2	Aglongbè	4	0	0	4	0	4	100.00
3	Agonmè	2	1	0	1	0	1	50.00
4	Aïta	6	4	2	0	0	0	n.a
5	Aklampa	2	0	0	2	1	1	50.00
6	Akodéha	4	1	2	1	0	1	25.00
7	Azohè-aliho	4	1	1	2	1	1	25.00
8	Bozoun	11	3	2	6	1	5	45.45
9	Dasso	11	3	0	8	0	4	72.73
10	Dogla	8	2	0	6	3	3	37.50
11	Dokoui-Dôho	2	0	2	0	0	0	n.a
12	Ewè	3	0	1	2	0	2	66.67
13	Gakpé	3	0	1	2	0	2	66.67
14	Gbodjoko	10	3	2	5	0	5	50.00
15	Gobé	3	0	1	2	1	1	33.33
16	Itchougan	4	2	1	1	0	1	25.00
17	Kissamè	2	1	0	1	0	1	50.00
18	Koto-agadjaligbo	4	2	1	1	0	1	25.00
19	Kouékouékanmè	3	0	0	3	0	3	100.00
20	Koundokpoé	5	2	0	3	0	3	60.00
21	Madjrè	3	1	0	2	0	2	66.67
22	Mbéga	2	0	1	1	0	1	50.00
23	Odo-Agban	2	1	1	0	0	0	n.a
24	Oko-akaré	3	0	1	2	0	2	66.67
25	Okoutaossé	3	0	1	2	0	2	66.67
26	Pira	4	1	0	3	3	0	n.a
27	Sagon	7	2	1	4	0	4	57.14
28	Sèdjè	11	1	3	7	0	7	63.64
29	Setto	3	0	1	2	1	2	33.33
30	Sissèkpa	11	2	0	9	2	7	63.64
31	Soclogbo	3	0	0	3	0	3	100.00
32	Togbin	2	0	0	2	0	2	100.00
33	Vacon	8	4	0	4	0	3	50.00
34	Zinvié	10	4	0	6	0	6	60.00

H+A+ landraces cultivated by many households on large Area, H+A− landraces cultivated by many households on small area, H−A− landraces cultivated by few households on small area, *TNL* total number of landraces, *NEL* number of elite landraces, *NRL* number of rare landraces, *NIL* number of newly introduced landraces, *NTL* number of threatened landraces, *RDL* (%) rate of diversity loss

(Table 8). Among them the most important are stem color, leaf shape and color (Table 8). Various skin and flesh color were observed with the sweet potato cultivars inventoried and used by the farmers to describe their cultivars after harvest. Pink, red or purple color is predominant for the skin while for the

Table 6 List, maturity cycle and villages of abundance of the elite cultivars

S/N	Cultivars	Maturity cycle (month)	Villages of abundance
1	Deux couleurs	3,5	Vacon
2	Afodjouba	3	Koto-Agadjaligbo
3	Ahôkpémi	2,5	Dogla
4	Amigonou	4	Azohè-aliho
5	Avougo kâ	4	Sagon
6	Awoliwêli	4	Koundokpoé
7	blêdékoun 1	3	Aïta
8	blèdéssa	2,5	Dogla
9	Bomankan	3	Sissèkpa
10	Bombo	3	Yêvié
11	Bombo 1	4	Gbodjoko, Sokan
12	Bombo 2	4	Gbodjoko, Sokan
13	Dékpogohoun	3	Aïta,
14	Dokoui vôvô	3–4	Agonmè
15	Elèhan akpara	3–5	Issaba, Koto-agadjaligbo
16	Epiè	4	Odoagban
17	Gboâdô	3–4	Gbodjoko, Sokan
18	Gbontin djitô	4–5	Kissamè
19	Gbonti djito 2	5	Adjacomè
20	Glokan	2,5–3	Gbodjoko, Bozoun
21	Gouti djon	4,5	Madjrè
22	Hanmankan	2–3	Gbodjoko, Sokan
23	Hèviosso	3–6	Dasso, Sèdjè
24	Idoki funfun	3–4	Issaba, Oko-akaré
25	Janvier kan	2,5	Bozoun, Gbodjoko
26	Koïdokpon 2	3–4	Gbodjoko
27	Konalôgô	3	Vacon
28	Kounalôgô	2,5	Aïta
29	Mèlégonou	3,5	Vacon
30	Mèlégonou 2	3,5	Vacon
31	Nanpèra	3	Pira
32	Oyoé vèè	4	Bowé
33	Sagon kan	3	Dasso
34	Tchénkédé	3	Aïta
35	Vobodouaho	3	Sagon, Sèdjè, Sissèkpa, Yêvié, Bozoun
36	Vobodouaho 1	3	Dasso
37	Vorto	4	Koundokpoé

flesh the white colour is most represented (Fig. 3). These folk taxonomy parameters are all among the sweet potato descriptors used by many authors (Tairo et al. 2008; Rukundo et al. 2015) in the morphological characterization and classification of sweet potato germplasm. This indicates that Benin sweet potato farmers have a good knowledge of their material and therefore their indigenous knowledge should be capitalized by geneticists and breeders as reported on fonio (Dansi et al. 2010), yam (Loko et al. 2013), sorghum (Dossou-Aminon et al. 2015) and traditional leafy vegetables (Adjatin et al. 2012; Sanoussi et al. 2015) for better orientation of their action plan.

Table 7 Farmers perception of principal reasons of sweet potato varietal diversity loss

Type of reasons	Reasons of diversity	% of responses
Agronomic (70.75 % of responses)	Low productivity	21.77
	Lack of planting material	15.65
	Inadaptability to all type of soil	12.24
	Long production cycle	10.20
	Introduction of new varieties	6.80
	High sensitivity to pests and diseases	2.04
	Small size roots	1.36
	Short post maturity underground shelf life	0.68
Culinary (17.69 % of responses)	Too high dry matter content	7.48
	Too high sugar content	5.44
	Low dry matter content (wattery)	2.72
	Short post-harvest shelf life	1.36
	High sensitivity to oxydation after peeling	0.68
Economical (7.48 % of responses)	Lack of selling market flow	6.12
	Low market value	1.36
Health (4.08 % of responses)	Existence of side effects	4.08

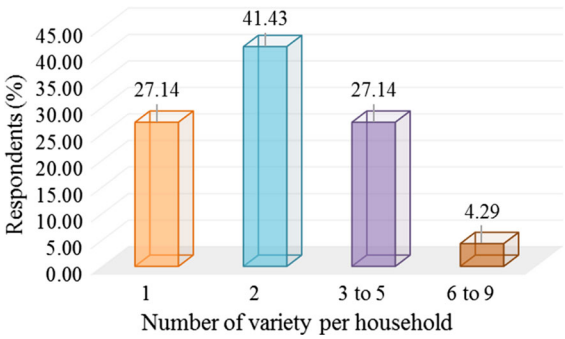


Fig. 2 Number of sweet potato cultivars maintained by household

Relative importance of vitamin A rich sweet potato cultivars and farmers' cultivars preference criteria

Flesh color is good indicator of vitamin A content in sweet potato (Vimala et al. 2011). Burri (2011) and Ellong et al. (2014), reported that carotenoid concentrations essentially are responsible for cream to orange flesh color and the more intensive is the color, the higher is the carotenoid/vitamin A content. Subject to synonymy, over 30 % of the cultivars are cream, yellow or orange fleshed (Fig. 3). This result indicates a potential richness of the study area in vitamin A rich sweet potato that can be valorized through several food products such as flakes (Sjafrina and Aminah 2014), chips (Esan et al. 2015) and especially infant formula (Amagloh et al. 2013, Sanoussi et al. 2013) to combat malnutrition and mainly vitamin A deficiency (using food approaches) in Benin and elsewhere particularly among children who are the most vulnerable.

Within the existing diversity, preference for cultivars depends on the consumers or the farmers as their preference criteria for sweet potato cultivars varied significantly (Table 8). For farmers, agronomic performance criteria were the most important (53.96 % of response) while with the consumers, organoleptic, technological and culinary criteria representing 78.79 % of the responses were the most sought after.

Since low productivity, low planting materiel production capacity, inadaptability to all types of soil and late maturity were the main reasons of abandoning of cultivars it is normal that high yielding (23.31 % of responses), resistance to pests and diseases (10.53 %), High vegetative development for sufficient planting material (0.75 %), adaptability to all type of soil (5.26 %) and early maturity (5.26 %) were highlighted among the farmer's preference criteria of sweet potato cultivars (Table 9). These two well correlated set of information confirmed the good

Table 8 Morphological traits used by farmers to identify varieties at vegetative stage and their importance in the study area

Organ	Parameters	Group survey (% of responses)	Individual survey (% of responses)
Stem	Stem color	18.06	17.43
	Stem size	6.25	3.67
	Length of stem	1.04	0.92
	Pubescence of stem	1.04	1.38
	Number of nodes	1.04	0.00
	Color of nodes	0.69	1.83
Veins	Abaxial vein color	8.33	8.72
Leaves	General shape of leaves	45.14	49.54
	Color of leaves	14.24	10.09
	Immature leaves color	3.82	1.38
	Color of petiole	0.35	4.59
Flowers	Color of flowers	–	0.46

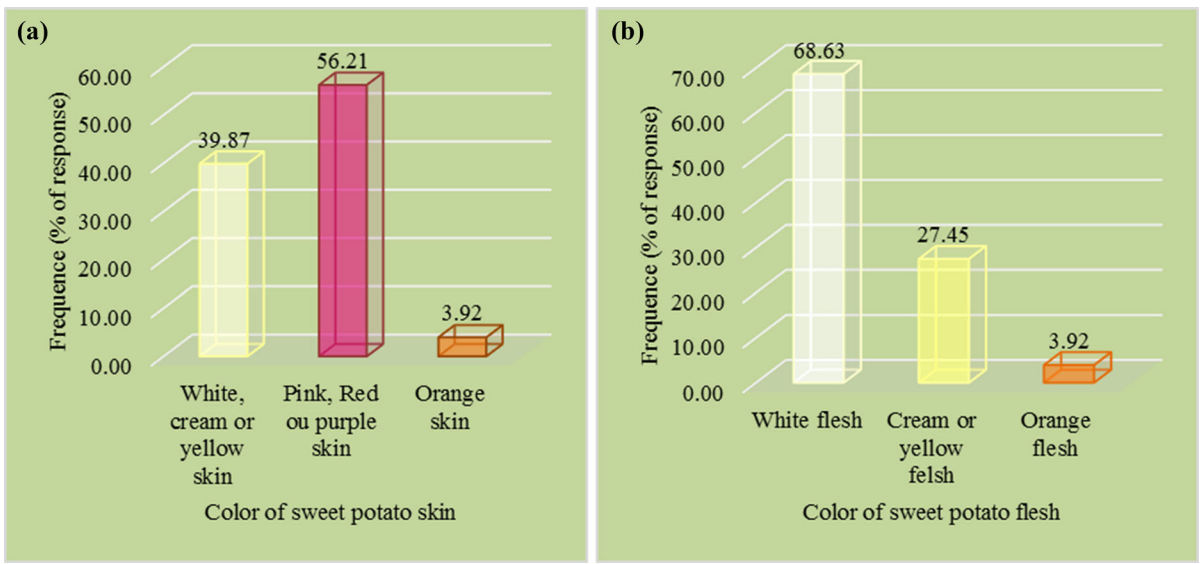


Fig. 3 Representativeness of skin (**a**) and flesh (**b**) color in the sweet potato cultivars collected through the study area

knowledge of the crop by the farmers surveyed. Our result is similar to the findings of Njukuwe et al. (2013) on farmers preference criteria of cassava in Cameroon who reported that farmers generally preferred early maturing, high yielding and pests and diseases resistant cultivars.

Among the organoleptic, technological and culinary preference criteria, the high dry matter content is privileged by both farmers and consumers (Table 9). Similar result was also reported in Uganda (Zawedde et al. 2014). Ukpabi et al. (2010) and Sesay et al. (2013) reported that high dry matter content and low peel loss are important farmers selection criteria in yam genotype for processing into secondary products. As indicated for cassava (Njukuwe et al. 2013), the other minor criteria also play an important role and should not be neglected. Consumption with nil side effects (5.05 % of responses) was raised mainly by the consumers. In fact during the survey, 74.03 % of respondents reported sweet potato consumption may cause side effects on health. The most frequent diseases such hernia, stomach ache and hemorrhoid

Table 9 Farmer's and consumer's preference criteria of sweet potato cultivars in Benin

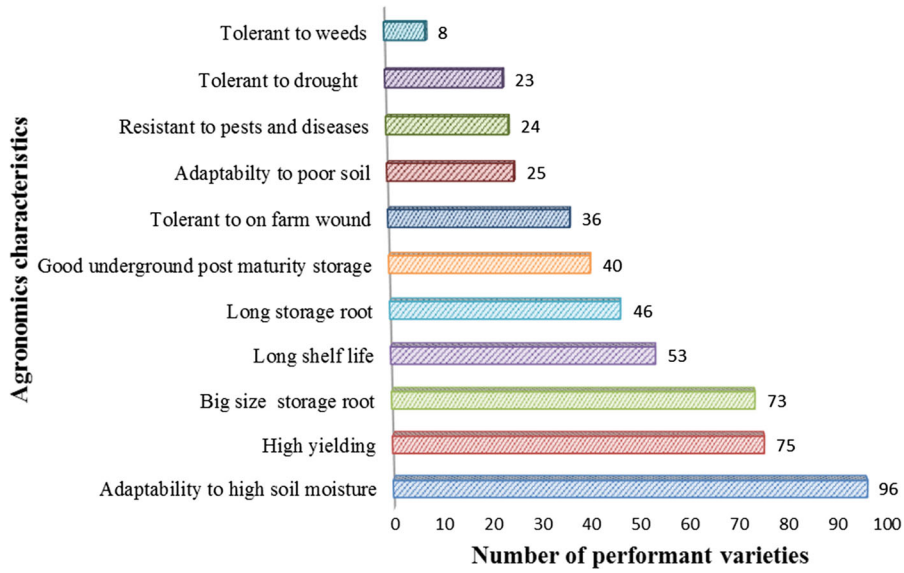
Categories of criteria	Preference criteria	Consumer's (% of response)	Farmers (% of response)	Ranking
Agronomics criteria (56.39 % of responses for farmers/ 13.13 % for consumers)	High productivity	n.a	23.31	1
	Resistant to pests and diseases	n.a	10.53	3
	Large sized tuberous root	4.04	6.77	5
	Adaptability to all types of soils	n.a	5.26	7
	Early maturing cultivars	n.a	5.26	6
	Long post-harvest shelf life	1.03	3.76	11
	High vegetative development for sufficient planting material	8.08	0.75	14
	Low stem ramification	n.a	0.75	15
Organoleptic, technological and culinary criteria (43.61 % of responses for farmers/86.87 % for consumers)	High dry matter content	34.34	15.04	2
	High sugar content	28.28	7.52	4
	Medium or low sugar content	6.06	5.26	8
	Consumption with nil side effect	5.05	3.01	10
	Highly colored flesh	3.03	3.76	9
	Goog flavor and appetizing	3.03	n.a	
	Good market value	2.02	3.01	11′
	white colored flesh	2.02	n.a	
	Fast cooking	1.01	n.a	
	Easy to peel after cooking	1.01	2.26	13
	Friability	1.01	n.a	
	Low browing capacity	n.a	0.75	
	Low fibbers content	n.a	3.01	12

(Hômin vodoun in Fon language) are mentioned by 37.66, 16.88 and 6.50 % of respondents respectively. As other illness, dysentery and sexuality problems as well as asthma, mycoses, pimples, allergies, tinea and cough were also reported. The high sweet taste of the storage roots is perceived by the majority of respondents (71 %) as the determinant of the harmful side effects. Producers give importance to market value. This is not surprising as producers always sell part of their harvest to face their numerous household needs.

Participatory evaluation of the sweet potato cultivars inventoried

As it has been done on yam in Benin (Loko et al. 2015) it is important for development or breeding purpose, to have a database on the performance of the cultivars and to know the availability of best performing cultivars per evaluation trait of economic importance. The results of the participatory agronomic evaluation of the cultivars inventoried are compiled in Fig. 4.

Few cultivars are tolerant to weeds, drought, and poor soil or resistant to pests and diseases while post-harvest storage and adaptability to high soil moisture were well furnished. Considering the culinary and technological parameters (Fig. 5) and subject to synonymies, 24 cultivars have a high colored flesh indicating the existence of non-negligible vitamin A rich sweet potato cultivars among those encountered in the study area. A full excel database is developed with the information gathered and will be useful for developers, germplasm specialists and breeders.



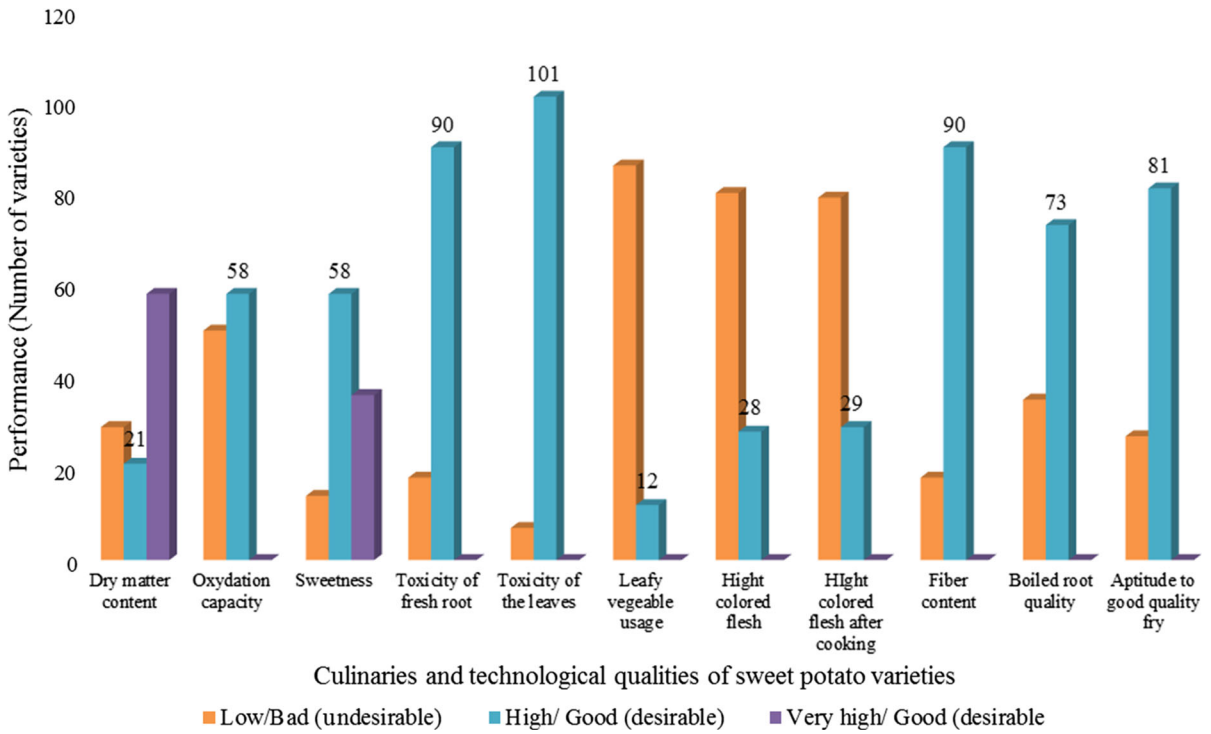


Fig. 4 Availability of performant sweet potato cultivars per agronomic trait of economic importance

Fig. 5 Availability of performant sweet potato cultivars per culinary and technological traits

With the database and based on the 13 most discriminant agronomic (High yielding, adaptability to poor soil, adaptability to high soil moisture, weeds tolerant, good underground post maturity storage, tolerance to on farm wounds) and culinary (browing aptitude, sweetness, fresh root and leaves toxicity, high colored flesh, fiber content, aptitude for good quality fries chips) evaluation traits, the UPGMA cluster analysis classified the 108 sweet potato cultivars inventoried and evaluated in eight groups (G1, G2, G3, G4, G5, G6, G7 and G8) at 65 % of similarity (Fig. 6) and in 92 morphological units. Each group or

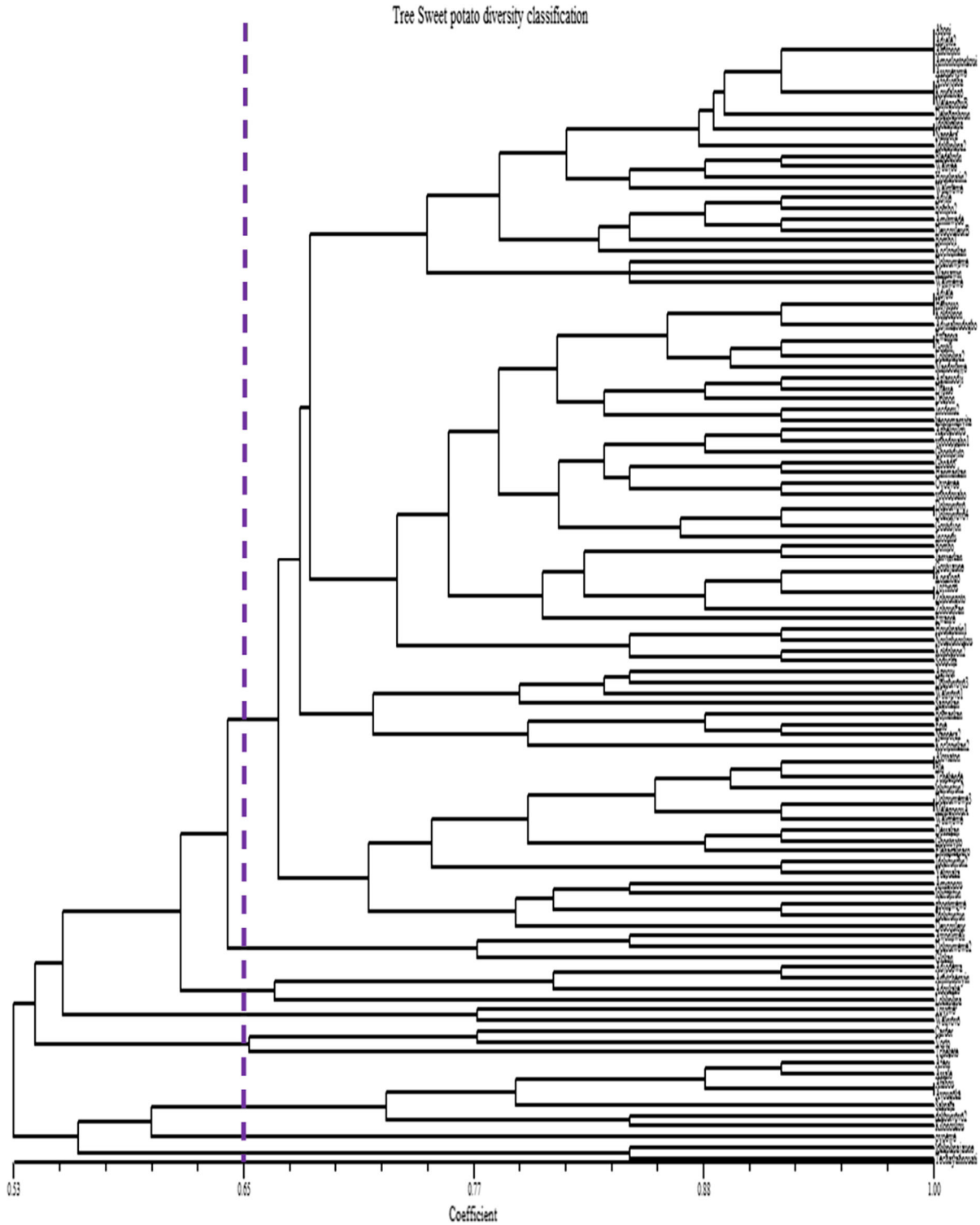


Fig. 6 UPGMA dendrogram showing the classification of 108 sweet potato cultivars into 8 groups based on the evaluation traits

unit has its set of characteristics exploitable by the scientific research and the development. Hence, it can be noted that the individuals of group 5 (Carder, Vortô, Tchèkètè) and 8 (LokikpikpaJaune, Téchanyanouati) present exclusively interesting agronomic and culinary characteristics (high productivity, good post maturity storage underground, good post-harvest shelf life, good aptitude for boiled roots and aptitude for good quality fries) while individuals from others groups cumulated both desirables and undesirables traits. The ex situ conservation of these last groups of landraces could be recommended for their future improvement.

Consumption and utilization of sweet potato in the study area

Throughout the study area, we observe that the majority of respondents (total 57.81 %) consume frequently sweet potato. However, significant proportions 23.44 and 18.75 % of respondents are consumed it moderately and rarely respectively. In the encoding frequencies of 1–5; we deduce that the score were 3.67; 3.60 and 3.76 for the study area, the Central and South regions respectively. There is no significant difference among the score recorded and thus we can conclude that the frequency of consumption of sweet potato does not vary following region and it is consumed frequently in all areas surveyed (Fig. 7).

Regarding the consumption methods of sweet potato in the study area, the majority of consumers (35.86 %) prefer the boiled root either unpeeled (30.81 %) or peeled (5.05 %). This coking practice is followed by the consumption of the fry (26.77 %), roasted (23.23 %) and then by the puree (14.14 %) in the study area.

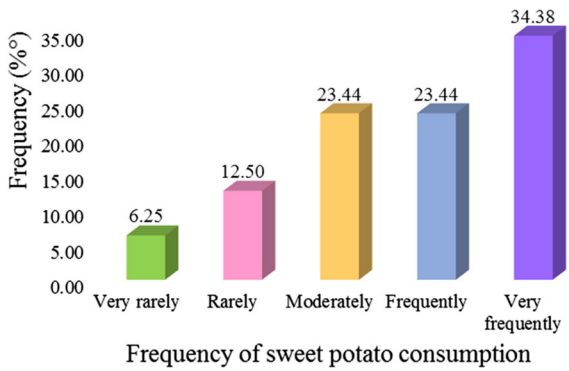


Fig. 7 Frequency of consumption of sweet potato by the respondents. *1* very rarely (1 per month), *2* Rarely (1 time per week), *3* Moderately (2 times per week), *4* Frequently (3 times per week), *5* very frequently (more than 3 times per week)

Out the consumer's surveyed 16.92 % have already be aware of the potential of vitamin richness of sweet potato while the rest (93.08 %) are not aware this potential at all. For the first class, the vitamin rich potential may be linked to yellow or orange coloring flesh (55.55 % of response) or to it sugared or salty taste (33.33 %) or to it high dry matter content (11.11 %). It can deduce that while there is a high lack of awareness on sweet potato vitamin potential among the people of the surveyed area, the indicators traits of this potential (yellow or orange colored flesh) is mastered by a wide range of respondents. Regarding the depreciation criteria, the sugar and the dry matter content rank the first. This last observation is in convenience with the preference criteria previously mentioned and show the coherence in the knowledge of the crop reported by farmers.

Among the respondents, some medicinal uses are recognized for sweet potato. Thus, the storage roots and leaves are involved in the treatment or prevention of certain diseases with a suspected aphrodisiac (4 responses), anti-anemic (2 responses), abortifacient (2 responses), wounds and burns healing (2 responses), anti-microbial (1 response), purgative (1 answer), analgesic (1 answer) blood pressure regulator (1 answer) and anti-malarial (1 response) effects. However these last remarks should be take into account with certain reservations due the fact it was reported by only few number of respondents and as not yet certify by biochemical and clinical test.

Seed system, germplasm collected and research perspectives

The methods farmers use to handle seeds are similar across regions but vary following the households. Therefore, during the intercropping season, the planting material are kept in the farm without any major effort (regeneration of the vine of the ancient plantation) or by collecting and keeping in cold place sometimes by side of river, lack or bath room or by regeneration from the storage root or by it cultivation on small farmland usually close to house as planting material propagation land. Then the plant material availability was not seen as a major problem in the

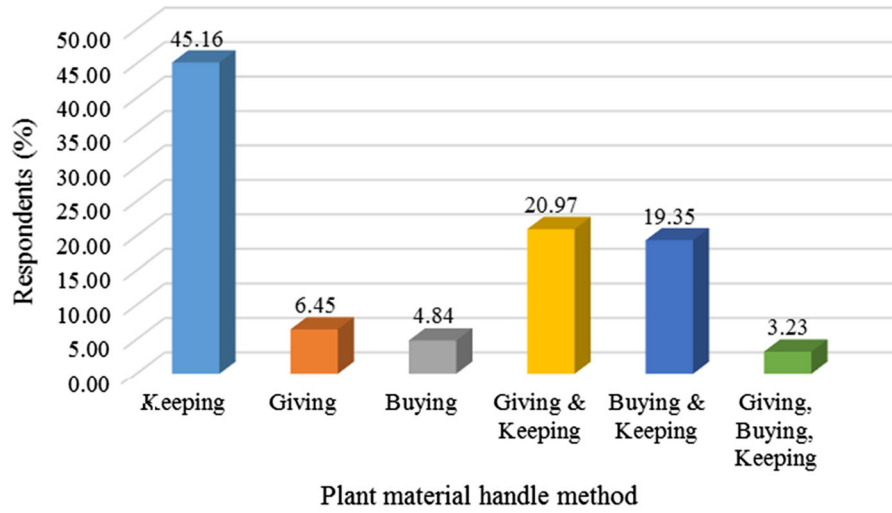


Fig. 8 Sources of planting material

rural areas surveyed because the plant can easily produce vine under farmers' conditions as reported for Gbolo (*Crassocephalum* ssp.) by Adjatin et al. (2012).

The sweet potato seed system management (Fig. 8) is dominated by keeping (45.16 % of respondents). This seed providing practices is followed by giving or exchange between the farmers (20.97 % of respondents) and buying (19.35 % of respondents). Here it can observe there is no institutional distribution or providing source such as local extension services of research and development offices. Then the seed system is managed by only the farmers and there is no yet institutional intervention for it management.

About one-third of respondents (34 %) do not know any way to keep the sweet potato for longer period while the rest (66 %) use five methods to preserve the storage root. Thus conservation in mounds (22 %) and overcrowding in a straw house or on the floor associated with fallen branches recovery (20 %) were the main preservation method registered. These methods is followed by crowding of storage root either into holes (10 %) or either in a cool and dry place (8 %) or the dusting with either ash (4 %) or either *Sarcocephalus latifolius* leaves "Coman in Fongbé" mixed with shea butter (2 %).

One hundred and eight varieties of sweet potatoes were collected throughout the survey zone. The number of varieties sampled varied from one to eleven per village. Plant stem were collected from plants under cultivation in home gardens or in the fields, packaged and numbered according to well established guidelines for germplasm collection (Guarino et al. 1995). The germplasm collected was established in the experimental field for research purposes especially for agromorphological and molecular characterization of the cultivars collected for establishment of future sweet potato breeding program. It is also planned to conduct deep study of (macro and micro) nutrients and phytochemical composition of the colored flesh varieties for their future valorization to contribute to vitamin A deficiencies alleviation within the region especially among the children.

Conclusion

This study shows the existence of certain varietal diversity (about 108 varieties under synonymy) of sweet potato in South and Centre of Benin among which the yellow and orange flesh varieties. The South region is the zone of the highest diversity and could be recommended as the site of in situ conservation of sweet potato varietal diversity in Benin. Unfortunately, the crop is limited by some constraints particularly the hardness of cultural practices and attack of diseases and pest which can affect the diversity on farm management (and thus it conservation) but could be solve research efforts.

Through the study area, it is consumed frequently as boiled or fried but suspect to induce side effects which is barrier for its promotion. As the varietal diversity loss is very high in certain region, the lack of general knowledge on its potential richness in vitamin

A is observed. Thus, their promotion and use through the creation of new value added product which conserving their nutritional potential will be highly recommended for the well-being of the local population on the one hand. On the other hand the evaluation of the nutritional profiles and technological capacity of each variety as well agro morphological characterization to clarify the synonymy among the diversity could be the next research step for the promotion of the species.

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Compliance with ethical standard

Conflict of interest No conflicts of interest between the authors of this research papers.

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