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RESEARCH ARTICLE

Assessment of cassava (*Manihot esculenta* Crantz) diversity, loss of landraces and farmers preference criteria in southern Benin using farmers' participatory approach

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Abstract Cassava (*Manihot esculenta* Crantz) is one of the highly produced and consumed food crops in Benin Republic. Through the application of participatory research appraisal tools and techniques, such as direct observations, group discussions and field visit, cassava production constraints, the diversity at the community level and farmers' varieties preference criteria were assessed in southern Benin. Base on national statistic cassava production fifty five (55) villages were selected and surveyed in the southern Benin. Descriptive statistics were used to analyse the data collected. About 11 constraints were listed by farmers, and the most important were low productivity, low post-maturity underground storage capacity of the roots of some cultivars, viral disease (cassava mosaic disease), susceptibility to high soil moisture, and lack of early maturing cultivars, which together accounted for 68.02 % of the total responses. Additionally, a total of 125 existing landraces were recorded. The distribution and extent pattern revealed 59 elites cultivars (cultivated by many households and on large areas) that were further grouped into 23 categories based on their agronomic, technological and culinary characteristics. In most of the villages, the farmers' perception of cultivar loss was based on abandonment of some cultivars due to their poor agronomic (69.12 % of responses) and culinary and/or technological attributes (30.88 % of responses). Within the existing diversity, cultivar choice or preferences are based on 22 culinary, technological, agronomic and economic criteria and their importance vary across the different department. Among these criteria, the most important were high productivity, good quality of the gari, early maturity and good friability accounted together for 48.12 % of the total responses. The presence of duplicates or synonyms was also observed and it is suggested that both morphological and molecular characterization and classification be carried out for better identification of cultivars.

Keywords Benin · Cassava · Diversity · *Manihot esculenta* · Preference criteria · Production constraints

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Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important food crops in the tropics, where it plays a critical role in ensuring food security for millions of households (Turyagyenda et al. 2012; Rabbi et al. 2014). It's also an important cash crop, which thrives where most other crops fail (Tumuhimbise et al. 2014). The storage roots provide more dietary energy per hectare than any other staple crop, making it the mainstay of small holder farmers in the tropics with limited access to agricultural inputs (Asare et al. 2011; Eze and Nwibo 2014). The carbohydrate production from cassava is about 40 % higher than rice and 25 % higher than maize, making it a suitable raw material for industrial production of ethanol, starch, adhesives, bio-fuels, glucose syrup among other uses (Tonukari 2004; Osun et al. 2014). The leaves are edible as well and are a rich source of proteins, vitamin C and other nutrients (Esuma et al. 2012; Nzeh and Ugwu 2014). Apart from industrial use of starch and human consumption, cassava can also be processed for use as animal feed.

Throughout Benin Republic, cassava is grown as a major root crop for cash, food, feed and raw material for the production of starch, alcohol and confectioneries. Cassava is grown across all agro-ecological zones, where it is produced by over 70 % of farmers and consumed by more than 50 % of the population (Hongbete et al. 2011) as various food products (boiled cassava, gari, lafun, etc.). Due to the crucial role it plays in food security, nutrition and income generation of the rural poor, Benin governor has supported and found many project on cassava which included cassava production, introduction of improve cassava varieties in some localities, identification of cassava enemies, improve of cassava production system, cassava processing into many products (IFAD website 2000) and assess of diversity using RAPD markers (Tonukari et al. 1997). Nonetheless, some farmers have continued to grow local cassava varieties that are important as potential genetic resources for cassava breeding programmes. However, little progress has been done on documentation of local cassava varieties in association with farmers in Benin Republic. As a result, there is insufficient information on the diversity at community level, the preference criteria through the different regions.

The improvement of cassava production for food security and poverty alleviation in Benin Republic will surely require the use of many modern cultivars that are resistant to pests and diseases, better adapted to climate change and have qualities desired by both producers and consumers. The generation of a breeding programme therefore depends on understanding and application of farmers' knowledge and preferences to develop cultivars that are widely adoptable and adaptable. The major objective of this study was therefore, to conduct ethno-botanical survey in the largest cassava producing zone in Benin Republic, in order to (a) identify factors affecting cassava production in southern Benin; (b) assess the diversity of cassava landraces within communities and the factors affecting this diversity; (c) identify total elite cassava grown in southern Benin and (d) document farmers' preference criteria for cultivar selection for use in breeding and extension programs.

Materials and methods

Study area

The study was conducted in southern Benin, the region with the highest cassava production in the country (National Statistics Data Base). Southern Benin is partitioned into three mega Departments (Atlantique-Littorale, Mono–Couffo and Ouémé–Plateau) inhabited by many ethnic groups spread across the surveyed area like (Adja, Cotafon, Sahouè and Watchi in Mono–Couffo), (Holly, Mahi, Nago–Yoruba and Ouémè in Ouémé–Plateau) and (Aïzo, Pédah, and Xwla in Atlantique-Littorale). This region is a relatively humid agro-ecological zone with two rainy seasons and a mean annual rainfall varying from 1100 mm to 1400 mm/year (Yabi and Afouda 2012). Mean annual temperatures range from 26 to 28 °C. The region has semi-deciduous forests or woodland and savannah woodland (Akoègninou et al. 2006). In order to sufficiently cover the study area and base on national statistic of cassava production 55 villages were selected and were surveyed from September to October 2013 throughout the different Departments (Fig. 1).

Data collection

Data were collected during expeditions to different sites through application of participatory research appraisal tools and techniques, such as direct

Fig. 1 Map of the southern Benin showing the geographical locations of the villages surveyed

observations, group discussions and field visits using structure questionnaire following Orobiyi et al. (2013). Discussions were conducted with the help of translators from each area. In each site, local farmers' associations were involved in the study to facilitate the organization of the meetings and the collection of data. Prior to the meeting, farmers were requested in advance to bring samples of the cassava cultivars they cultivate or knew about. 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. Farmers were then asked to list (vernacular names) and display different cultivars that they grow in their villages. Through

discussions, detailed agronomic, culinary quality characteristics of the listed cultivars were documented.

The distribution and extent of the cultivars were assessed using the Four Squares Analysis approach described by Dansi et al. (2010), Kombo et al. (2012), Gbaguidi et al. (2013). This method was used, at community level and with the participation of 20–30 cassava farmers with different age included both male and female. The Four Squares Analysis approach contribute to classify existing cultivars into four groups: cultivars cultivated by many households on large areas; cultivars cultivated by many households on small areas; cultivars cultivated by few households on large areas, and cultivars cultivated by few households on small areas. Later, detailed information was collected on each cultivar with the objective of understanding farmers' knowledge and preferences for specific cultivars. The Four Square Analysis method was also used to identify elite cultivars (cultivated on large areas and by many households) and assess the rate of loss of varieties (Kombo et al. 2012). The names of the landraces that have completely disappeared and the reasons of their abandonment were also documented.

The enlisted cassava cultivars were then evaluated for their agronomic and culinary characteristics in a participatory way through focus group discussions, using a predefined evaluation sheet and the two-level evaluation method described by Kombo et al. (2012). For a given variable, a variety was scored '1' when it is said to be performing and '0' when it is not. In total 10 agronomic (productivity, tolerance to poor soil, tolerance to high soil moisture, tolerance to weeds, post maturity in-ground storage capability, earliness, tolerance to virus diseases, tolerance to drought, suitability to all types of soil and storage quality of the chips) and 10 culinary et technological qualities (friability of the boiled root, quality of gari, palatability of the leaves, starch quality, toxicity of the root, quality of the dough produced with the flour, fiber content, poundability, starch content and quality of the chips) parameters were considered to evaluate the cultivars for their performance.

Additionally, data on production constraints were identified and arranged in their order of importance using focus group method as described by Dossou-Aminon et al. (2014). During the discussions in a given village, farmers were invited to list the different constraints in cassava production. Enlisted constraints were then ranked according to the order mentioned by the farmers. In each surveyed village and in group of 25–30 cassava farmers. Cassava farmers were invited to list the most and important criteria that should have a cassava varieties in order to be widely adopted in their village condition. The different criteria listed by farmers' were then ranked according to their importance.

Statistical analysis

Data was analysed using descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (villages, departments, study area) levels using Statistica 7.1 software. Shannon–Weaver diversity index was used to assess landrace diversity in the study area. The rates of cultivars loss (RCL) was calculated per village using the formula $RCL = [(n - k)/N] \times 100$, where n = number of cultivars cultivated by few households on small areas, k = number of newly introduced cultivars found in the fourth square, and N = total number of cultivars recorded in the village (Kombo et al. 2012; Gbaguidi et al. 2013). The relatedness between different elite cultivars (cultivated by many households on large areas observed in at least one of the villages) was analyzed using both agronomic and culinary traits including time to maturity, productivity, quality of gari, starch content, fiber content, quality of starch, post maturity in-ground storage capability, friability of the boiled root, storage quality of the chips and quality of the dough produced with the flour. For every elite cassava cultivar, each parameter was scored as '1' when the cultivar was perceived as good performing and '0' if not performing. Using this methodology, a binary matrix was compiled. Pairwise distances between cultivars were computed by NTSYS-pc 2.2 using the simple matching coefficient of similarity and a dendrogram was plotted with UPGMA cluster analysis (Rohlf 2000).

Results and discussion

Factors affecting cassava production in southern Benin

Based on farmer's responses and perception, eleven biotic and abiotic constraints hampering cassava

production in southern Benin was identified (Table 1). The most important constraints are low productivity of the landraces (15.49 % of responses), susceptibility to viral diseases (14.61 % of responses), low post maturity in-ground storage capability (13.97 % of responses), susceptibility to poor soils (13.05 % of responses), high soil moisture (12.44 % of responses), root rot disease (11.29 % of responses) and lack of early maturing cultivars (10.83 % of responses) (Table 1). In Africa and particularly in Benin, many cassava farmers use unimproved planting materials or landraces, traditional cultural practices characterised by late and random planting, poor weed control, and ignorance/lack of control of pests and diseases (Asare et al. 2011; Agre et al. 2015). The constraint of in-ground post-maturity storage capability raised by farmers reflects their multiple engagements in different agricultural products for sustainability. They generally grow diverse crops (2–4), thus lack of time to harvest their cassava when mature. Farmers also reported that they need to keep their plants in the field after maturity until a good market is available for them to sell their cassava harvest (Soulé et al. 2013). According to the farmers and based on the existing cultivars they grow, a delay of about a month after maturity results in root rotting or conversion of promising roots into fibres rendering them useless for any purpose.

The importance of various constraints for cassava production varied from one Department to another (Table 1). In Atlantique, soil infertility ranked first followed by low productivity and virus diseases. In Mono–Couffo, susceptibility of many cultivars to high soil moisture was first, while in Ouémé–Plateau, low productivity ranked first followed by susceptibility to viral disease (cassava mosaic disease). In the Department of Mono–Couffo for instance, cassava production is mostly concentrated in the fertile and humid valleys along Mono and Kouffo rivers, which are periodically and temporally flooded leading to root rots and/or early dropping of leaves for majority of the cultivars. In cassava production, high tuber yields can be obtained depending on the soil quality (Ajani and Onwubuya 2013). In the Department of Atlantique, soils are poor leading to low yields for almost all the crops including cassava. This information provided by the farmers coincides with the existing situation as reported by Winter et al. (2010), Rabbi et al. (2014) and Tumuhimbise et al. (2014) in other countries. The information provided by the farmers is very important to understand the existing situations in different regions to build strategies and improve cassava production.

Status of cassava diversity in southern Benin

In all the 55 surveyed villages based on farmers' knowledge, a total of 125 cassava cultivars were recorded. There is however a high probability that both synonyms (different varieties with same name)

Table 1 Constraints of cassava production in southern Benin

Constraints	Study area (% villages)	Variability between departments		
		Atlantique	Mono/Coufo	Ouémé/Plateau
Low productivity	15.49	15.27	11	18.20
Susceptibility to virus diseases	14.61	11.77	16	16.68
Low post maturity in-ground storage capability	13.97	13	13.46	15.46
Poor soils	13.05	16	11.10	12.04
Susceptibility to high soil moisture	12.44	11.11	17.11	10.09
Root rot	11.29	14	12.10	8.50
Lack of early maturing cultivars	10.83	11	8.50	14
Susceptibility to drought	3.08	4	4.03	1.20
Pest attack (root and chips)	2.27	1.88	2.02	3.22
Early drop of leaves	2.17	2.28	4.28	–
Susceptibility to weeds	1.13	1.03	1.13	1.23

and homonyms (same varieties with different names) exists within them. It is not certain that all 125 cultivars recorded in the study area are genetically distinct. In traditional agriculture, cultivars are often named after different places or people or ethnic group as it passes from hand to hand. Tamiru et al. (2008) and Otoo et al. (2009) reported this in a number of crops and the presence of homonyms and synonyms are also reported on cassava (Elias et al. 2001; Lekha et al. 2011; Kombo et al. 2012; Tumuhimbise et al. 2012). There is a need for detailed morphological and molecular characterization of the cultivars to identify duplicates based on actual genetic make-up of each of them. True-to-type identification of cultivars is a prerequisite for efficient management of crop genetic resources and proper seed systems in breeding efforts (Turyagyenda et al. 2012).

The number of cultivars per village varied from 3 to 21 (8 on average per village) (Table 2). Ikpédjilé village, located in the Department of Plateau recorded the highest number of cultivars (21 cultivars in total). Shannon–Weaver diversity index (H′) showed the presence of wide varietal diversity in the study area (H′ = 3.89). However, this diversity varied within and between Departments (Table 3), the Department of Oueme–Plateau presented the highest diversity (ten cultivars on average per village), while the Mono–Couffo Department presented the lowest diversity (six cultivars on average per village). The high diversity observed in the study area, particularly in Plateau Department, can be explained by the dynamic introduction of cassava cultivars with good agronomic, culinary and technological traits from neighbouring countries. These cultivars include "Odohoungbo, Idilèrou, Okin, Otègbèyè, Obasandjo" obtained, across the border, from Nigeria, the world's largest producer and repository of cassava diversity (Onubuogu et al. 2014).

Despite the availability of existing cassava diversity, only few cultivars (3 on the average per village) were cultivated by many households on large areas. Onubuogu et al. (2014) observed similar trends in many cassava producing wherein the production is mainly concentrated on a small number of elite cultivars cultivated by many households on large areas. According to cassava farmers, cultivars cultivated by many households on large areas are those that are economically profitable, and which possess almost all the desirable agronomic (high yield, early maturity, tolerance to viral diseases) and culinary and technological characteristics (good quality of gari, good friability of the boiled root and high starch content).

The loss or threat of cultivars in villages, where it was reported, varied from 9.09 to 71.43 % (42.48 % on average) of the existing cultivars (Table 2). The highest rate (71.43 %) was recorded in Gbozounmè village and the lowest was found in Igbo-Edè village. The rate of cultivars loss (RCL) was high in many villages thus indicating the need of developing strategic and concerted approaches to ensure sustainable in situ and ex situ conservation (Jarvis et al. 2000; Dossou-Aminon et al. 2014). However in some villages like Atchannou, Atchonsa, Goutin, Tori Bossito, Voli and Zamè, no threatened cultivar was reported.

The reasons for abandonment or loss of cultivars was mostly related to their poor agronomic performance (69.12 % of responses) among which low productivity, very late maturity, low post maturity in-ground storage aptitude of the roots, and high susceptibility to viral diseases was most important and accounted for 20.54, 15.94, 10.25 and 8 % of responses, respectively (Table 4). The introduction of new cultivars with good agronomic, culinary and technological qualities is also considered to be one of the major factors for abandonment of some of the cultivars and this contributed to 9.14 % of the responses. The culinary and technological aspects accounted for only 30.88 % of the response, of which the most important were the high toxicity of the root and the leaves and the bad quality of the chips (peeled, sliced and dried roots). According to cassava farmers, these raisons have been the cause of abandoned of many cassava cultivars across the different villages surveyed in southern Benin. The lack of unthreatened cultivars in some villages is not an indication of their good diversity conservation capacity but rather the result of a long farmer selection process that ended with a group of cultivars that are really suitable and adapted to their agro-ecological conditions.

Identification of the elite cassava cultivars in southern Benin

Taking the name of varieties into account and among 125 cassava varieties recorded in this region, a total of 59 varieties were identified as elite (cultivated by many households on large areas in at least one village).

Table 2 Diversity, distribution, extent and rate of cultivars loss per village

No.	Villages	TNC	Distribution and extent				NIC	NCD	RCL (%)
			M+S+	M+S−	M−S+	M−S−			
1	Agbodji	9	1	2	1	6	1	5	55.56
2	Agohoué-Balimè	4	1	0	0	3	1	2	50
3	Ahozon	7	2	0	0	5	2	3	42.86
4	Aidjèdo	7	3	0	0	4	3	1	14.29
5	Akpadanou	14	6	0	0	8	1	7	50
6	Alligoudo	5	1	0	0	4	1	3	60
7	Atchannou	5	1	1	0	3	0	0	0
8	Atchonsa	4	3	1	0	0	0	0	0
9	Avagbé Akpanrou	7	3	1	0	3	0	3	42.86
10	Avégamè	3	1	1	0	1	0	1	33.33
11	Ayou Tokpa	4	3	0	0	1	0	1	25
12	Azohouè-Aliho	6	3	0	0	3	1	2	33.33
13	Damè-Wonkon	12	7	0	0	5	1	4	33.33
14	Danhoué	9	2	0	0	7	2	5	55.56
15	Dawè Centre	9	2	1	0	6	1	5	55.56
16	Dédékpoué	11	2	1	0	8	4	4	36.36
17	Djanglanmey	4	2	0	0	2	0	2	50
18	Ewè	9	5	0	1	3	0	3	33.33
19	Gbada	4	2	1	0	1	0	2	50.00
20	Gbakpodji	9	2	2	0	5	0	5	55.56
21	Gbégon	11	3	1	2	5	1	4	36.36
22	Gbéhoué	7	1	2	0	4	0	4	57.14
23	Gbékandji	9	3	1	0	5	1	4	44.44
24	Gbézé	4	1	2	0	1	0	1	25
25	Gbozounmè	7	1	1	0	5	0	5	71.43
26	Glo Glégbodji	7	3	0	0	4	1	3	42.86
27	Goutin	10	3	7	0	0	0	0	0
28	Hêkanmê	8	1	0	0	6	1	5	62.50
29	Ichagba Holli	12	6	3	0	3	1	3	25
30	Igbo-Edè	11	3	5	0	3	2	1	9.09
31	Ikpédjilé	21	5	0	2	14	2	12	57.14
32	Illikimou	13	4	2	1	6	1	5	38.46
33	Ita-Djèbou	12	4	2	1	5	5	0	0
34	Kokohoué	3	2	0	0	1	0	1	33.33
35	Koussi	4	2	0	0	2	0	2	50
36	Lokogba	4	2	1	0	1	0	1	25
37	Massè	6	1	1	0	4	1	3	50
38	Odomèta	9	2	4	0	3	1	2	22.22
39	Ofia	8	1	1	2	4	0	4	50
40	Oko-Akaré	14	7	1	2	6	2	4	28.57
41	Omou	19	9	4	0	6	1	4	21.05
42	Ouédèmè Adja	6	3	1	0	2	0	2	33.33
43	Ouedème Péda	8	2	0	0	6	0	6	75

Table 2 continued

No.	Villages	TNC	Distribution and extent				NIC	NCD	RCL (%)
			M+S+	M+S−	M−S+	M−S−			
44	Ouèdo	12	6	2	0	4	2	5	41.67
45	Sègbèya	5	2	0	0	3	0	3	60
46	Sodji	9	3	3	0	3	1	2	22.22
47	Sokpètinkon	9	2	4	1	2	0	2	22.22
48	Tchikpé	3	1	0	0	2	0	2	66.67
49	Toffo-Agué	4	3	0	0	1	0	1	25
50	Tori-Bossito	4	3	0	0	1	1	0	0
51	Vakon Azohouè	7	3	0	0	4	1	3	42.86
52	Voli	3	1	1	0	1	1	0	0
53	Yôkpô Djèvié	8	3	0	0	5	0	5	62.50
54	Zamè	3	1	0	0	2	2	0	0
55	Zèbou Togoudo	6	2	0	0	4	0	4	66.67
	Mean	**8**	**3**	**1**	**0**	**4**	**1**	**3**	**42.48**

TNC total number of cultivars, *M+S+* cultivars cultivated by many households on large areas, *M+S−* cultivars cultivated by many households on small areas, *M−S+* cultivars cultivated by few households on large areas, *M−S−* cultivars cultivated by few households on small areas, *NIC* newly introduced cultivars, *NDC* number of disappeared cultivars, *RCL* rate of cultivars lost

Table 3 Variability of diversity through departments

Diversity zone	TNV	Shannon index	Minimum	Maximum	Diversity mean
Atlantique	15	2.65	4	12	7 ± 0.55^{a}
Mono–Couffo	18	2.79	3	11	6 ± 0.53^{a}
Ouémé–Plateau	22	3.01	4	21	10 ± 0.45^{b}
Study area	55	3.89	3	21	8 ± 0.78^{a}

TNV total number of villages surveyed, cultivars mean values in the same column followed by different letters differ significantly ($P < 0.05$)

Table 4 Reasons for cassava varieties loss and their relative importance in the study zone

Category	Reasons	Percentage of responses (%)
Agronomic (69.12 %)	Low productivity	20.54
	Very late maturity	15.94
	Low post maturating in –ground storage aptitude	10.25
	Introduction of new cultivar	9.14
	Susceptibility to virus disease	8
	Susceptibility to high soil moisture	5.25
Culinary (30.88 %)	Toxicity of leaves and roots	13.49
	Bad quality of cassava chips	7.25
	Bad quality of gari	5.80
	High fibber content	4.34

However, the prevalence of these elite varieties differs according to the villages. For example, cultivars Odohougbo, Agric, Hombêtè, Idilèrou and Kofferogou are widely distributed and cultivated in large areas in southern Benin (Table 5) while elite cultivar "Globo" appeared in many villages as cultivated by few

Table 5 Distribution and extent of selected elite cassava cultivars grown in southern Benin

No.	Vernacular names	Villages, distribution and extent
2	Adjatin Daho	Avagbé (++); Damè-Wogon (++); Yokpô djevié (++)
3	Agbahizi	Gbakpodji (++)
6	Agric Rouge	Agbodji (++); Ahozon (++); Aîdjêdo (++); Akpadanou (++); Alligoudo (++); Atchannou (++); Azohouè-Aliho (++); Damè-Wogon (++); Danhoué (++); Dédékpoué (++); Djanglanmey (++); Gbada (++); Gbakpodji (++); Gbéhoué (++); Gbékandji (++); Gbozounmè; (++); Glo Glégbodji (−); Goutin (++); Ikpédjilé (−+); Ita-djèbou (++); Ouédèmè Adja (++); Ouèdèmè Péda (++); Sègbèya (++); Sokpètinkon (++); Tori-bossito (++); Vakon Azohouè (++)
10	Antiôta	Massè (++); Gbégon (++); Ichagba Holli (++)
11	Atiwé	Damè-Wogon (++); Gbada (++); Gbozounmè (−)
12	Awlivou	Ouedo (++)
15	Bassia	Akpadanou (−); Gbékandji (++); Glo Glégbodji (++); Ahozon (++); Goutin (−); Sokpètinkon (+−)
16	BEN	Ewè (++); Ikpédjilé (++); Ofia (−+); Omou (+−)
20	Globo	Agbodji (−); Ahozon (−); Alligoudo (−); Avégamè (−); Dawé-centre (−); Dédékpoué (−); Gbakpodji (−); Hèkanmè-centre (−); Kokohoué (++); Lokogba (−); Ouédèmè Adja (−) Tchikpé (−); Yôkpô Djèvié (−); Zèbou Togoudo (−)
21	Holégoumè	Aïdjèdo (++)
22	Hombêtê	Agbodji (−); Ahozon (++); Aîdjêdo (−); Alligoudo (−); Atchannou (−); Avagbé (−); Ayou Tokpa (++); Azohouè-Aliho (++); Danhoué (−); Dawé-centre (−); Djanglanmey (++); Gbakpodji (+−); Gbéhoué (−); Hèkanmè-centre (−); Ouédèmè Adja (−); Ouèdèmè Péda (−); Ouèdo (−); Sègbèya (−); Toffo-Agué (−); Tori-bossito (−);Yôkpô Djèvié (++); Zèbou Togoudo (++)
23	Idilêrou	Ewè (++); Gbégon (++); Ichagba Holli (++); Igbo-Edè (++); Ikpédjilé (−); Illikimou (++); Ita-djèbou (+−); Odomèta (++); Ofia (++); Oko-Akaré (++); Omou (++); Sodji (++)
25	Kofèorogoun	Gbégon (−); Massè (−); Igbo-Edè (++); Ikpédjilé (−); Ofia (−); Ichagba Holli (++); Oko-Akaré (−); Omou (++); Sodji (−)
26	Kpêkê	Atchonsa (++); Avagbé (++); Dawé-centre (++); Damè-Wogon (++); Hèkanmè-centre (++); Gbozounmè (−); Glo Glégbodji (−); Ouèdo (++); Vakon Azohouè (++);Yôkpô djevié (++)
27	Öbassandjô	Ikpédjilé (++)
28	Odohoungbo	Damè-Wogon (++); Ewè (++); Gbégon (+−); Ichagba Holli (++); Igbo-Edè (−); Ikpédjilé (−); Illikimou (−); Ita-djèbou (−+); Massè (−); Odomèta (+−); Ofia (−); Oko-Akaré (++); Omou (++); Sodji (+−)
29	Ôfêguê	Ichagba Holli (+−); Igbo-Edè (−); Ikpédjilé (−); Odomèta (++); Oko-Akaré (++); Omou (++); Sodji (++)
30	Ôkôiyawo	Damè-Wogon (++); Ikpédjilé (−); Illikimou (++); Massè (−)
31	Ötêgbêyê	Ichagba Holli (−); Igbo-Edè (+−); Ikpédjilé (−); Oko-Akaré (++); Omou (+−)
32	RB1	Ewè (++); Ikpédjilé (++); Ita-djèbou (++); Ofia (−+); Oko-Akaré (++); Omou (+−)
33	RB2	Ewè (++); Ikpédjilé (−)

(++) cultivars cultivated by many households on large areas, (+−) cultivars cultivated by many households on small areas, (−+) cultivars cultivated by few households on large areas, (–) cultivars cultivated by few households on small areas

households on small areas (Table 5). In many villages where this cultivar was found, it is always said newly introduced and the stems are not available to many households and this may be the reason for its lower distribution and adoption. Additionally, it has been reported that several improved cassava varieties were introduced in the region by the national agricultural research institute (INRAB) and the Roots and Tubers Development Programs (PDRT). During the survey, only few varieties BEN, RB, TMS and Agric have been identified as improved cultivars and are widely cultivated. It is more likely that farmers did not adopt all the introduced improved cultivars and consequently they were no longer cultivated. Another probable justification could be that the names of those cultivars have been changed by farmers and the

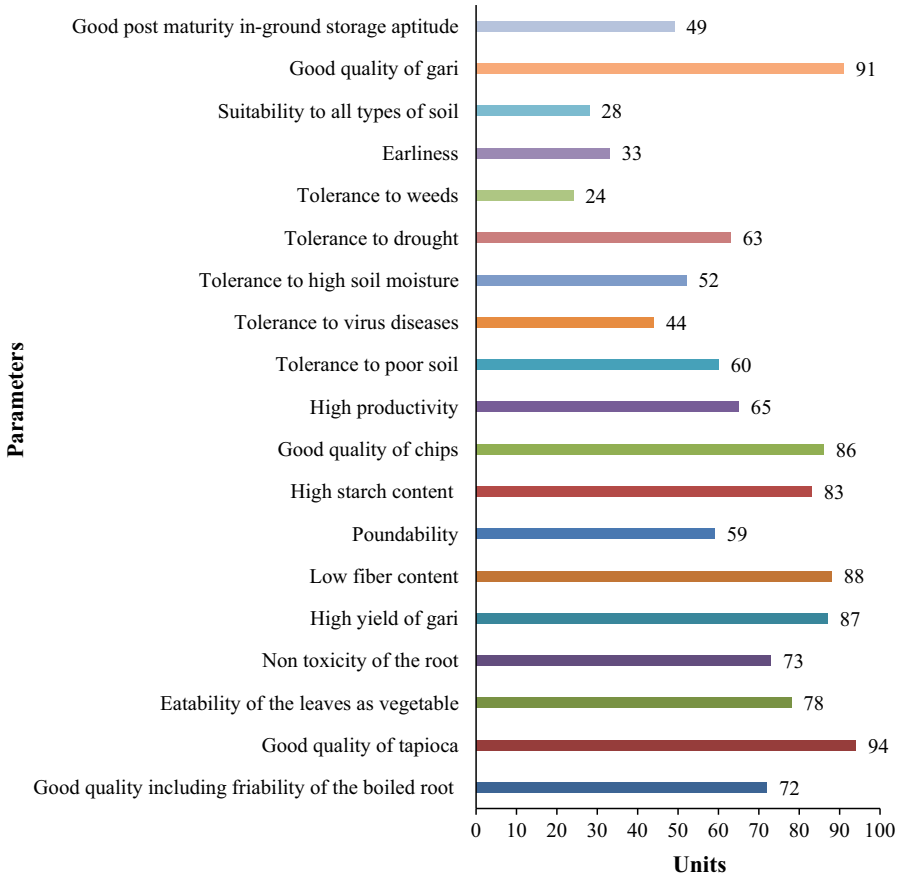

Fig. 2 Participatory evaluation

improve line name have been lost. It is therefore critical to use DNA fingerprinting to verify the identity and establish the traceability of these cultivars in southern Benin.

Subject to synonymy and among the 125 cassava cultivars recorded and evaluated through participatory approach, 94 have good quality of tapioca, 91, 88, 87, 86 and 83 were reported to have a good quality of gari, low fiber content, high yield of gari, good quality of chips, and high starch content respectively (Fig. 2). More tests such as agronomic and physico chemical evaluation should be done to confirm these characteristics. However, very few cultivars with traits such as in-ground storage aptitude, tolerance to virus diseases, early maturity, suitability to all types of soil and tolerance to weeds were identified. It is then important to further research in other parts of the country in order to identify more cultivars meeting those requirements for breeding purposes.

Relationship among elite cultivars

The relationship between the 59 elite cultivars was analysed using hierarchical cluster analysis (Fig. 3). At 75 % of similarity, Cluster analysis partitioned the elite cultivars into 6 groups namely G1–G6 (Fig. 3). For example, G1 is characterized by the early maturing cultivars with good taste while G2 grouped both late and early maturing cultivars with high productivity, high capability for in-ground storage and low fiber content. The cultivars in this cluster also represented individual clones with good quality of gari, starch content and good quality of the chips. Only two cultivars from cluster 3 represented high yield of gari with good quality and high starch content. Cluster 4 (G4) assembles the early maturing cultivars with good taste and good quality gari but showed poor in-ground storage capacity. G5 and G6 grouped together late maturing varieties that are high yielding but had roots

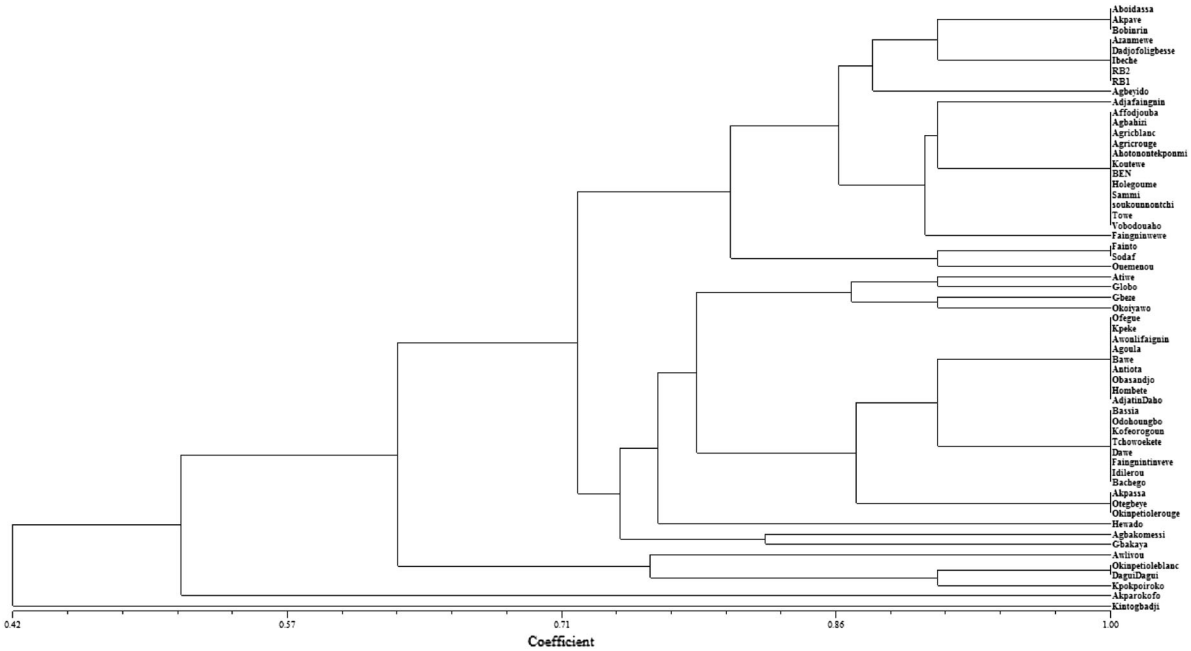

Fig. 3 Dendrogram showing the classification of the cultivars based on agronomic, culinary and technological traits

with poor taste. Some of these diverse cultivars selected from each of the clusters can be further promoted after DNA fingerprinting (identification of duplicates) for wider distribution to broaden the genetic base of cassava varieties in the region.

Farmers' cultivars preference criteria

Twenty (20) preference criteria (culinary, technological, agronomic and economic) were identified across the surveyed study areas (Table 6). Among these, nine were related to culinary and technological qualities and were recorded in 50.55 % of villages while 10 were related to the agronomic and were cited in 46.71 % of villages and one was of economic importance (Table 6). However, these criteria varied from one department to another (Table 6). In Atlantique, culinary qualities were mentioned in 46.69 % of the villages while agronomic criteria accounted for 51.31 % of villages. Contrary to this, in Ouémé–Plateau Departments, culinary quality were the most important criteria and accounted for 54.17 % of the villages while agronomic criteria accounted for 43.11 % of villages. Among the twenty preference criteria considered by farmers while making a choice of a cultivar, high yield, good quality including friability and the taste of boiled root, quality of gari and early maturity are considered the most important. In almost all the cassava growing communities of sub-Saharan Africa, these parameters are considered by cassava farmers, consumers and researchers as first selection criteria of economic importance for production (Essono et al. 2008; Njukwe et al. 2013; Tumuhimbise et al. 2012; Salvador et al. 2014). In the Mono–Couffo Department area inhabited by Adja and Cotafon ethnic group, good quality including friability and good taste (mealiness) of boiled root were the most important traits for farmers. This result could be explained by the fact that for these ethnic groups, boiled cassava plays a potential role in generating income for households. In Plateau department which is mainly inhabited by Nago and Yoruba ethnic groups, quality of chips commonly called as lafun was considered important because is considered as main food for this ethnic group. This variation in the selection criteria observed in southern Benin throughout Departments or socio-ethnic groups (Table 6) indicated the existence of some specificity traits that

Table 6 Farmers' cultivar preference criteria and their importance through departments

Category of criteria	Preference criteria	Study area (% of villages)	Departments		
			Atlantique	Mono–Couffo	Ouémé–Plateau
Culinary Trait	Good quality of boiled root	13.98	14	20.44	7.51
	Quality and yield of gari	12.53	10.18	11.25	16.15
	High starch content and good quality of tapioca	7.74	8	5	10.21
	Good quality of chips	4.75	2	1.25	11
	Aptitude of leaves to be consumed as vegetable	3.77	4.10	7.20	–
	Suitable for many food processing	3.49	4.10	2.49	3.87
	Low fiber content	2.76	4.10	1.04	3.15
	Good poundability	1.19	0.21	2.14	1.21
	Root very easy to peel	0.36	–	–	1.07
	Total	50.55	46.69	50.81	54.17
Agronomic	High productivity	14.73	15.18	14	15
	Early maturity	10.53	10.12	11.25	10.23
	Suitability to all type of soil	3.94	7.12	1.24	3.47
	Tolerance to root rot	3.85	4.13	3.41	4
	Tolerance to high soil moisture	3.20	4.22	2.51	2.88
	Tolerance to virus diseases	3.13	3	3.15	3.24
	High post maturity in-ground storage aptitude	2.91	4	2.58	2.14
	Tolerance to drought	1.87	2	1.45	2.15
	Tolerance to weed	1.53	0.33	4.25	–
	Tolerance to pest and rodent	1.03	1.21	1.88	–
	Total	46.71	51.31	45.72	43.11
Economic	High market value	2.73	2	3.47	2.72

should be taken into account in varietal exchange or participatory and decentralized cassava breeding programs.

Conclusion

The present study revealed the existence of significant diversity of cassava landraces in Benin Republic, but this diversity is unequally distributed, as observed throughout the study area. This study provided the opportunity to identify and prioritize the constraints (biotic and abiotic) that cassava farmer's face within southern Benin, document the varietal diversity and farmer's preferences for choosing a specific variety. With regard to the actual status of the diversity, complementary approaches should be developed and implemented for conservation through utilization of cassava genetic resources in Benin, and farmers' preferences should be taken into account in breeding programs. Agro-morphological and molecular characterizations are also recommended for clarifying mislabelling and varietal identification. Phytochemical analysis should be conducted in order to know the nutritional content of some cultivars for their sustainable use. The study may also be extended to other regions of Benin Republic, where cassava is a very important crop for food security and income generation.

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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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