International Journal of Plant & Soil Science

24(1): 1-13, 2018; Article no.IJPSS.43470
ISSN: 2320-7035

Assessment of the Phenotypic Diversity of Sweet Potato Landraces (*Ipomoea batatas* L.) Cultivated in Benin Using Morphological Descriptors

Arsène Mahoutondji Doussoh[1*], Justine Sossou Dangou[2], Corneille Ahanhanzo[1], Serge Sètondji Houedjissin[1] and Armel Kayodé Assogba[1]

[1]Central Laboratory of Plant Biotechnology and Plant Breeding, Department of Genetic and Biotechnology, Faculty of Science and Technology, University of Abomey-Calavi, 01 BP 526, Cotonou, Republic of Benin.
[2]Laboratory of Research in Applied Biology, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Republic of Benin.

Authors' contributions

This work was carried out in collaboration between all authors. Author AMD designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors AMD, AKA and SSH collected and analyzed the data. Authors JSD and CA guided, funded the research work and reviewed and corrected the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/43470
Editor(s):
(1) Dr. Peter A. Roussos, Agricultural University of Athens, Laboratory Pomology, Greece.
(2) Dr. Abigail Ogbonna, Department of Plant Science and Technology, Faculty of Natural Sciences, University of Jos, Nigeria.
Reviewers:
(1) Oluwatoyin Sunday Osekita, Adekunle Ajasin University, Nigeria.
(2) Manasi Dash, Trident School of Biotech Sciences, India.
(3) R. Mahalakshmi, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/26046

Original Research Article

Received 19th June 2018
Accepted 21st August 2018
Published 30th August 2018

ABSTRACT

Aim: *Ipomoea batatas* is one of the tuberous roots produced in Benin for its nutritional and economic interests and whose diversity remains unknown. This research work aims to evaluate the phenotypic variability within sixty-four landraces collected in South and Central Benin.
Methodology: The trials were carried out using randomised complete block design with three replicates at the experimental site of Agricultural School of Akodeha at southern part, of Benin during two consecutive rainy seasons, September to November 2016 and May to July 2017.

**Corresponding author: E-mail: dousserne@yahoo.fr;*

Nineteen (19) qualitative and six (6) quantitative traits selected from the descriptors of the International Potato Center were used. An ascending hierarchical classification based on the discriminant variables was carried out.

Results: The results obtained showed the existence of a morphological diversity within the collection studied for the principal color of the stem, the pubescence of the top of the stem, the general appearance of the leaf, the pigmentation of the abaxial vein of the stem, the leaf, the predominant color of the skin of the tubers, the secondary color of the flesh of the tubers and its distribution. The landraces were grouped into seven (7) classes with qualitative variables. Similarly, with the quantitative variables, 7 groups were obtained.

Conclusion: The information from this study provides a useful database for moving towards molecular genetic characterisation of sweet potato landraces in Benin and for their *in vitro* and *ex situ* conservation for breeding programs.

Keywords: Ipomoea batatas; phenotypic diversity; landraces; morphological descriptors; Benin.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a vegetatively propagated crop that belongs to the family Convolvulaceae and represents the fifth important crop in developing countries after rice, wheat, maize and cassava [1]. It is a source of carbohydrates, vitamins A, fiber, protein and minerals [2-4]. In some countries of the world including India, sweet potato is considered to be an alternative subsistence crop to cereals owing of its ability to develop in a difficult environment, its significant production potential and easiness to fit to various climatic condition [5]. This helps to answer the food needs of the poorest populations. In Benin, sweet potatoes are grown in all agro-ecological zones in small areas of varying fertility [6]. It is mainly produced in southern and central Benin in the departments of Atlantic, Oueme and Zou which covers about 70% of national production [7]. Despite its socio-cultural and economic importance, sweet potato remains a poorly developed crop compared to cassava and yam, and neglected for researchers in Benin, while its contribution to food security is not negligible [8]. Previous works on endogenous knowledge of sweet potatoes in Benin has revealed the existence of significant local diversity. Several landraces have been identified and collected with local names that differ from one socio-cultural group to another and are dependent on the origin and agronomic performance of the variety [7]. There is a risk of over or underestimation of the real diversity that exists. Indeed, several genetically different landraces can be referred by the same name or the same landrace designated by several local names [9]. Similarly, producers of the study area use various morphological criteria for recognising landraces. The assessment of diversity by morphological descriptors and molecular markers is useful in creating in vitro collections and ex-situ preservation of germplasm of sweet potato varieties. Likewise, it contributes to the identification of successful landraces in terms of production, tolerances to the difficult conditions and resistance to pests and diseases [10]. The assessment of phenotypic diversity is the first step in establishing the similarities and differences between the landraces collected and in identifying of the different genotypes of sweet potato. To this end, it is a database that can be used to introduce some varieties in *in vitro* culture for their production and preservation. Phenotypic evaluation by morphological descriptors has been widely used in the world on sweet potatoes [11,12] and in Benin on several crops including yam [13], cassava [14]. As for sweet potato, the state of knowledge of its diversity from the morphological point of view remains very limited. The present work aims to assess the phenotypic diversity within sweet potato landraces collected in Benin using morphological descriptors. Specifically, it is (a) to analyse the morphological variability within sweet potato landraces collected in Benin; (b) to determine the structure of diversity from the most significant qualitative and quantitative variables.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material used includes sixty-four (64) sweet potato landraces subject to synonym. These landraces were collected from September 2015 to February 2016 in thirty-five (35) villages of Southern and Central Benin (Table 1).

Table 1. List of sweet potato landraces used for characterisation

N°	Codes	Vernacular names	Collection sites	Localities	Areas of Benin
1	B01	Adogbo	Agbossoukota	Bonou	South
2	B02	Adoukonoun	Aïzè Zokpodji	Ouinhi	Center
3	B03	Afeni	Aïzè Zokpodji	Ouinhi	Center
4	B04	Aglansodji	Gbodjoko	Abomey-Calavi	South
5	B05	Aguékan	Dèkin	Adjohoun	South
6	B06	Ahotonon	Gbèdogogléta	Adjohoun	South
7	B07	Ahouawé	Ouédja	Ouinhi	Center
8	B08	Alolouhè	Zonmon Kossou	Ouinhi	Center
9	B09	Aloviaton	Zoungo	Ouinhi	Center
10	B10	Amihouédé	Agbossoukota	Bonou	South
11	B11	Amitchéwin	Sissèkpa	Adjohoun	South
12	B12	Assalè	Ouédja	Ouinhi	Center
13	B13	Atabou	Kpoto	Zangnando	Center
14	B14	Avougo	Zonmon Kossou	Ouinhi	Center
15	B15	Avouzou	Zonmon Kossou	Ouinhi	Center
16	B16	Blè	Sissèkpa	Adjohoun	South
17	B17	Blèdessa	Glédjiaga	Adjohoun	South
18	B18	Bombo vovo	Sokan	Abomey-Calavi	South
19	B19	Bombo wéwé	Sokan	Abomey-Calavi	South
20	B20	Deux couleurs	Ayita	Sakété	South
21	B21	Djantro	Zonmon kossou	Ouinhi	Center
22	B22	Djètè hli	Houin Tokpa	Lokossa	South
23	B23	Djlondou	Agbossoukodji	Bonou	South
24	B24	Djodéwa	Sissekpa	Adjohoun	South
25	B25	Djowamon	Awokpa	Zè	South
26	B26	Doki èlèhin akpao	Takou	Kétou	South
27	B27	Doki èlèhin akpao 1	Takou	Kétou	South
28	B28	Doki founfoun	Onigbolo	Pobè	South
29	B29	Doki kpikpa	Onigbolo	Pobè	South
30	B30	Dokouin vovo	Affamè	Tori	South
31	B31	Dokouin wéwé	Affamè	Tori	South
32	B32	Dokoui carotte	Gbodjoko	Abomey-Calavi	South
33	B33	Flamagbontin	Houndji centre	Klouékanmè	South
34	B34	Gboado	Gladji	Abomey-Calavi	South
35	B35	Gbontin djouin 1	Toviklin centre	Toviklin	South
36	B36	Gbontin djouin 2	Kaïhoué	Lalo	South
37	B37	Hanmankan	Gbodjè	Abomey-Calavi	South
38	B38	Hinkingnin	Ahomey Glon	So Ava	South
39	B39	hounkpatinkan	Ahomey Glon	So Ava	South
40	B40	Jardinkan	Sissèkpa	Adjohoun	South
41	B41	Klodjigbontin	Yobohoué	Lalo	South
42	B42	Koidokpon	Glo Fanto	Abomey-Calavi	South
43	B43	Kpotoun	Aïzè Zokpodji	Ouinhi	South
44	B44	Madouhouè	Glédjiaga	Adjohoun	South
45	B45	Massawin	Sokan	Abomey-Calavi	South
46	B46	Mètché	Sokan	Abomey-Calavi	South
47	B47	Mètché 1	Agbanta	Dangbo	South
48	B48	Oyou ové	Danhoué	Houéyogbé	South
49	B49	Oyou ové klokosintounlè	Tohoun	Houéyogbé	South
50	B50	Petitkan	Sokan	Abomey-calavi	South
51	B51	Sagoukan	Glédjiaga	Adjohoun	South
52	B52	Sodoutcha	Gbodoko	Abomey-Calavi	South
53	B53	Tchokoto	Ayita	Sakété	South
54	B54	Tolikan	Glédjiaga	Adjohoun	South

N°	Codes	Vernacular names	Collection sites	Localities	Areas of Benin
55	B55	Vobodouaho	Sokan	Abomey-Calavi	South
56	B56	Vobodouaho LR	Agbossoukodji	Bonou	South
57	B57	Vododouaho 1	Kpoto	Zagnanado	Centre
58	B58	Wèli houéton	Awokpa	Zè	South
59	B59	Wèli vovo	Hadjanaho	Abomey-Calavi	South
60	B60	Wèli wéwé	Hadjanaho	Abomey-Calavi	South
61	B61	Wétékan	Agbossoukodji	Bonou	South
62	B62	Zohoucan	Glédjiaga	Adjohoun	South
63	B63	Zohoungbo	Aïzè Zokpodji	Ouinhi	Center
64	B64	Zohoungoto	Agbossoukodji	Bonou	South

2.2 Experimental Conditions

The experiments were conducted at the Agricultural School of Akodeha experimental site in Comè located at southern part of Benin during two rainy seasons consecutive (September to November 2016 and May to July 2017). This region is characterised by an average rainfall of 1200 mm/year. The average temperature varies between 25°C and 29°C with a relative humidity of 69% and 97% [15]. These conditions were favourable for the establishment of the sweet potato crop. The vigorous cuttings of 25 cm with four to five nodes of each landrace were sown on prepared hillocks. The randomised complete block design with three replications was used and each block composed of three (3) lines of 22 hillocks approximately 20 cm of deepness. Each landrace was planted on three hillocks. The distance between plants was 1 m and between lines was 1.5 m. No fertiliser was used for the soil. The field was maintained by manual weeding.

2.3 Data Collection

Data collection was done at 60, 90 and 120 days after planting. Twenty-five (25) variables including nineteen (19) qualitative and six (6) quantitative (Table 2) were selected from the descriptors of sweet potato of Bioversity International (CIP / AVRDC / IBPGR) [16].

Table 2. Qualitative and quantitative variables used

Variables	Codes	Scoring
Qualitative variables		
Plant type	PT	3-Low ; 5-Medium ; 7-High ; 9-Total
Predominant Vine color	PVC	1- Green ; 2- Green with some purple spots ; 3- Green with several purple spots ; 4- Green with many dark purple spots ; 5- Mostly purple ; 6- Mostly dark purple ; 7- Totally purple ; 8- Totally dark purple
Secondary vine color	SVC	0-Absent ; 1- Green base ; 2- Green tip ; 3- Green nodes ; 4- Purple base ; 5- Purple tip ; 6- Purple nodes
Vine tip pubescence	VTP	0-Absent ; 3- Sparse ; 5- Moderate ; 7- Dense
General appearance of leaf	GAL	1-Rounded ; 2- Reniform ; 3- Heart-shaped ; 4- Triangular ; 5- Hastate ; 6- Lobed ; 7-Almost divided
Type of lobe of leaf	TLL	0-No lateral lobes ; 1- Very slight ; 3- Slight ; 5- Moderate ; 7- Deep ; 9- Very deep
Shape of the leaf central lobe	SLCL	0-Absent ; 1- Toothed ; 2-Triangular ;3- Semi-circular ; 4-Semi-elliptic ; 5-Elliptic ; 6-Lanceolate ; 7-Oblanceolate ; 8-Linear
Abaxial leaf vein pigmentation	ALVP	1-Yellow ; 2-Green ; 3-Purple spot in the base of main rib ; 4-Purple spot in several veins ; 5-Main rib partially purple ; 6-Main rib mostly or totally purple ; 7- All veins partially purple ; 8-All veins mostly or totally purple ; 9-Lower surface and veins totally purple
Mature leaf color	MLC	1-Yellow-green ; 2- Green ; 3-Green with purple edge ; 4-Greyish-green ; 5-Green with purple veins on upper surface, 6-Slightly purple ; 7-Mostly purple ; 8-Green upper surface, purple lower surface ; 9-Purple on both surfaces
Immature leaf color	ILC	1-Yellow-green ; 2- Green ; 3-Green with purple edge ; 4-Greyish-green ; 5-Green with purple veins on upper surface, 6-

Variables	Codes	Scoring
		Slightly purple ; 7-Mostly purple ; 8-Green upper surface, purple lower surface ; 9-Purple on both surfaces
Pigmentation of Petiole	PP	1-Green ; 2-Green with purple near stem ; 3- Green with purple near leaf ; 4- Green with purple at both ends ; 5- Green with purple spots throughout petiole ; 6- Green with purple stripes ; 7-Purple with green near leaf ; 8-Some petioles purple, some others green ; 9-Totally or mostly purple
Usual flowering	UF	0-Absent ; 3- Sparse ; 5- Moderate ; 7- Dense
Predominant skin color of tubers	PSCT	1-White ; 2-Cream ; 3-Yellow ; 4-Orange ; 5-Brownish orange ; 6-Pink ; 7-Red ; 8- Purple-red; 9-Dark purple
Secondary skin color of tubers	SSCT	0-Absent ; 1-White ; 2-Cream ; 3-Yellow ; 4-Orange ; 5-Brownish orange ; 6-Pink ; 7-Red ; 8- Purple-red; 9-Dark purple
Predominant flesh color of tubers	PFCT	1-White ;2-Cream ; 3-Dark cream ; 4-Pale yellow ;5-Dark yellow ; 6-Pale orange ; 7-Intermediate orange ; 8-Dark orange ; 9-Strongly pigmented with anthocyanins
Secondary flesh color of tubers	SFCT	0-Absent ; 1-White ; 2-Cream ; 3-Yellow ; 4-Orange ; 5-Pink ; 6-Red ; 7-Purple-red ; 8-Purple ; 9-Dark purple
Distribution of secondary flesh color of tubers	DSFC	0-Absent ; 1-Narrow ring in cortex ; 2-Broad ring in cortex ; 3-Some cattered in flesh ; 4-Narrow ring in flesh ; 5-Broad ring in flesh ; 6-Ring and other areas in flesh ; 7-In longitudinal sections ; 8-Covering most of the flesh ; 9-Covering all flesh
Shape of tubers	ST	1-Round ; 2-Round elliptic ; 3-Elliptic ; 4-Ovate ; 5-Obovate ; 6-Oblong ; 7-Long oblong ; 8-Long elliptic ; 9-Long irregular or curved
Surface defects of tubers	SDF	0-Absent ; 1-Alligator-like skin ; 2-Veins ; 3-Shallow horizontal constrictions ; 4-Deep horizontal constrictions ; 5-Shallowlongitudinal grooves ; 6-Deep longitudinal grooves ; 7-Deep constrictions and deep grooves.
Quantitative variables		
Vine internode lenght	VIL	1-Very short (< 3 mm) ; 3-Short (3-5 mm) ; 5-Intermediate (6-9 mm) ; 7-Long (10-12 mm) ; 9-Very long (> 12 mm)
Vine internode diameter	VID	1-Very thin (< 4 mm) ; 3-Thin (4-6 mm) ; 5-Intermediate (7-9 mm) ; 7-Thick (10-12 mm) ; 9-Very thick (> 12 mm)
Main vine length	MVL	3-Erect (< 75 mm) ; 5- Semi-erect (75-150 mm) ; 7-Spreading (151-250 mm) ; 9- Extremely spreading (> 250 mm)
Number of leaf lobe	NLL	1,3,5,7 or 9
Mature leaf size	MLS	3-Small (< 8 cm) ; 5-Medium (8-15 cm) ;7-Large (16-25 cm) ; 9-Very large (> 25 cm)
Petiole lenght	PL	1-Very short (< 10 cm) ; 3-Short (10-20 cm) ; 5-Intermediate (21-30 cm) ; 7-Long (31-40 cm) ;9-Very long (> 40 cm)

2.4 Statistical Analysis

The STATISTICA version 7.1 software was used for data analysis. For qualitative variables, the linear logistic model was applied to select discriminant variables to differentiate landraces. A dendrogram based on these variables was constructed to group individuals into different classes. An analysis of variance (ANOVA) was performed to assess the variability of individuals within each group. For quantitative variables, a descriptive analysis (mean, minimum, maximum, standard deviation, coefficient of variation, standard deviation) was performed. Principal Component Analysis (PCA) and the correlations that exist between these variables were determined and a cluster analysis generated based on ward similarity coefficient.

3. RESULTS

3.1 Variability between Sweet Potato Landraces Based on Qualitative Variables

Discriminant analysis from the linear logistic model identified seven variables to differentiate

the landraces studied (Table 3). These were predominant vine color (PVC), vine tip pubescence (VTP), General appearance of leaf (GAL), abaxial leaf vein pigmentation (ALVP), Predominant skin color of tubers (PSCT), secondary flesh color of tubers (SFCT) and distribution of secondary flesh color of tubers (DSFC).

These variables showed variations within sweet potato landraces (Fig. 1). In fact, 60.94% of the landraces have their predominant vine color green against 1.56% totally purple. Of all the landraces collected, 45.31% have a moderate pubescence of vine tip against 6.25% that are absent. For general appearance of leaf, 34.38% and 31.25% of landraces have respectively lobed and triangular against 1.56% of rounded leaves. Similarly, 37.50% of these leaves have pigmentation of their green-colored abaxial vein against 1.56% of with purple spots in several veins. Tubers with white, cream and pink skin predominate (26.56% each). Most tubers (84.38%) haven't secondary flesh color. A significant number of landraces (68.75%) have flesh with a narrow ring in cortex compared to 4.69% where there are some scattered in flesh.

The cluster analysis based on Ward's Euclidean similarity distance from the discriminant variables ranked sixty-four (64) sweetpotato landraces in seven (7) groups (Fig. 3).

- Group G1 consisted of landraces with green vine that have sparse to moderate pubescence, leaves of varying form (heart-shaped, triangular or lobed) and tubers with white skin to cream.
- Group G2 consisted of landraces with green vine, leaves of varying shapes (hastate, triangular), tubers with cream skin and the presence of some scattered spots in the flesh of the tubers.
- Group G3 consisted of landraces with green vine with some purple spots, leaves with lobes or heart-shaped and partially purple veins and white or cream skin of tubers.
- Group G4 included landraces with mostly dark purple vine, triangular or heart-shaped leaves with purple spots in the base on main rib, tubers who have orange and purple-red skin, the flesh with a purple-red secondary color covering most of the flesh.

Table 3. Discriminant analysis from the linear logistic model of qualitative variables

Variables	Estimate	Standard error	Wald	Prob
PT	0.01	0.00	2.39	0.12
PVC	**-0.01**	**0.00**	**6.67**	**0.00****
SVC	-0.00	0.00	1.70	0.19
VTP	**-0.01**	**0.00**	**5.25**	**0.02****
GAL	**0.02**	**0.01**	**5.07**	**0.02****
TTL	-0.01	0.00	3.59	0.05
SLCL	0.00	0.00	0.11	0.73
ALVP	**0.01**	**0.00**	**4.79**	**0.02****
MLC	0.00	0.01	0.23	0.62
ILC	-0.00	0.00	2.57	0.10
PP	-0.00	0.00	1.96	0.16
UF	-0.00	0.00	0.044	0.83
PSCT	**0.01**	**0.00**	**5.92**	**0.01****
SSCT	-0.00	0.00	2.49	0.11
PFCT	-0.00	0.00	2.55	0.11
SFCT	**0.01**	**0.00**	**4.02**	**0.04****
DSFC	**-0.03**	**0.01**	**13.12**	**0.00****
ST	0.00	0.00	0.02	0.88
SDF	0.00	0.00	0.07	0.78
Echelle	16.15	0.82	384.00	0.00

PT : Plant type; PVC : Predominant vine color; SVC : Secondary vine color; VTP : Vine tip pubescence; GAL : General appearance of leaf; TLL : Type of lobe of leaf; SLCL : Shape of the leaf central lobe; ALVP : Abaxial leaf vein pigmentation; MLC : Mature leaf color; ILC : Immature leaf color; PP : Pigmentation of Petiole; UF : Usual flowering; PSCT : Predominant skin color of tubers; SSCT : Secondary skin color of tubers; PFCT : Predominant flesh color of tubers; SFCT : Secondary flesh color of tubers; DSFC : Distribution of secondary flesh color of tubers; ST : Shape of tubers; SDF : Surface defects of tubers

- Group G 5 contained landraces with mostly purple vine with moderate pubescence, triangular or heart-shaped leaves, red-skinned tubers and flesh with some scattered spots.
- Group G 6 contained landraces whose vine are green with some purple spots and having a moderate to dense pubescence, the leaves have lobes and have all their veins totally purple. The tubers have purple red skin.
- Group 7 has landraces with green vine with some purple spots, heart-shaped leaves with partially purple veins and purple-red tubers.

Table 4 showed an analysis of variance within each group. Thus, a significant difference at the 5% threshold within the groups G1, G2, G4, G5 and G7 was observed while there is no significant difference within the groups G3 and G6.

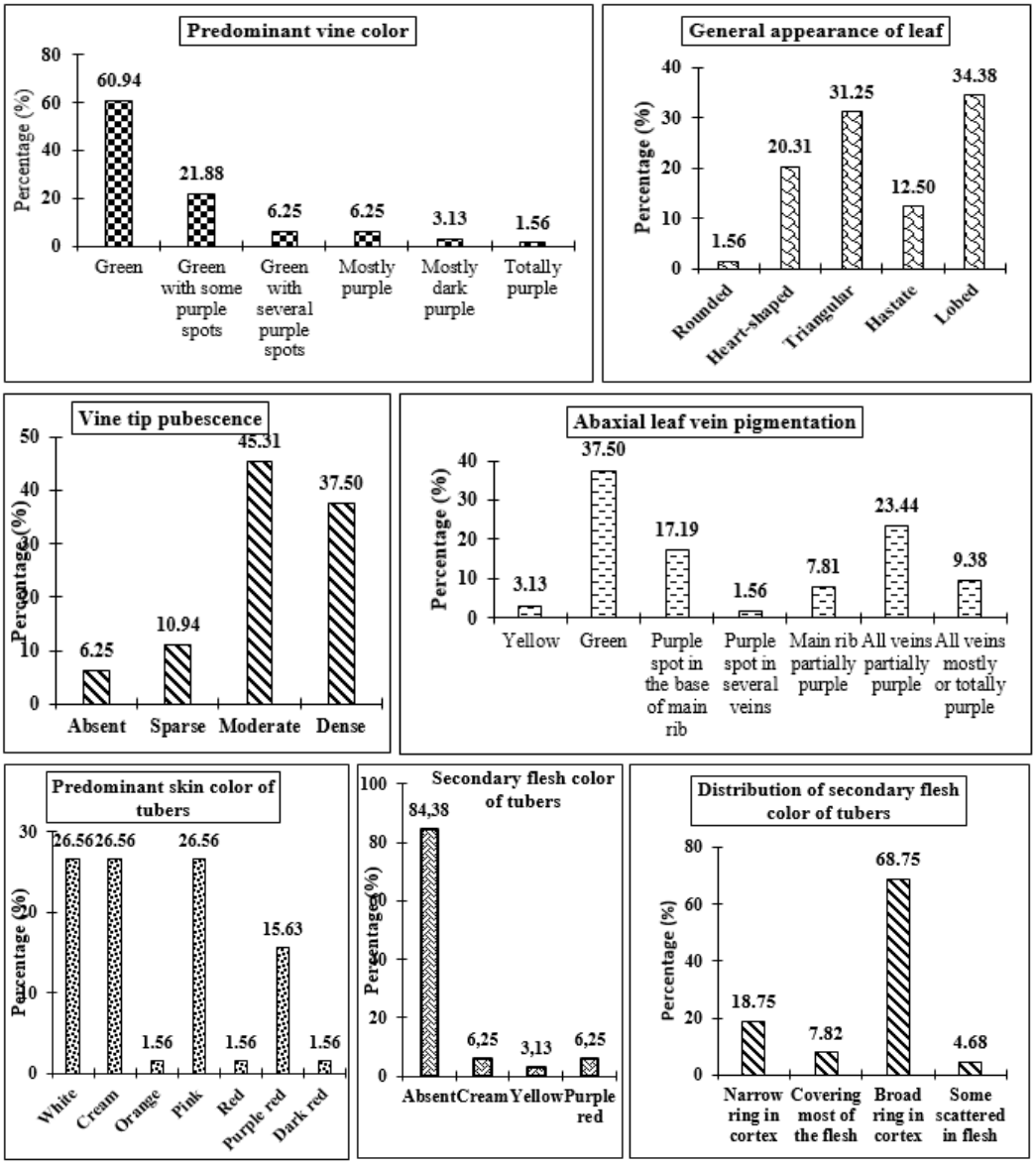

Fig. 1. Frequency of distribution of discriminant qualitative variables within sweet potato landraces

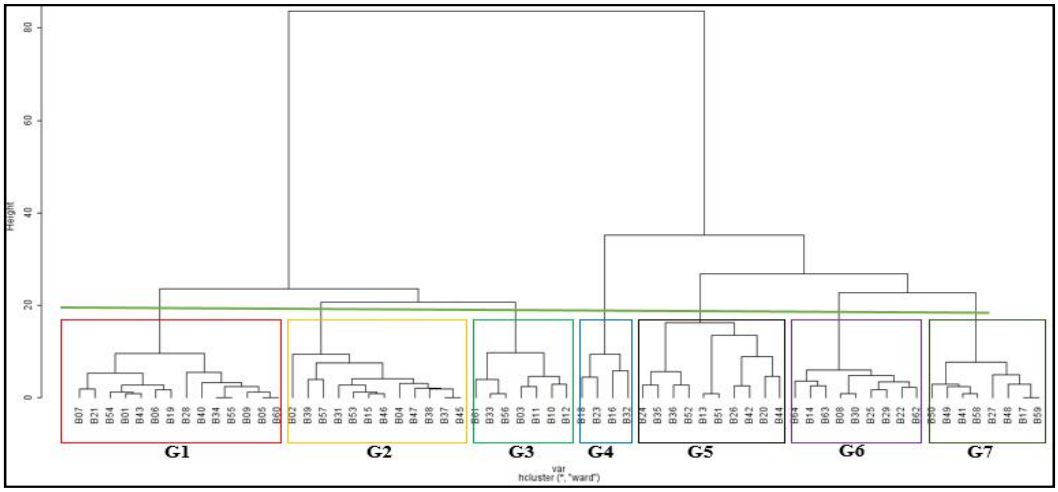

Fig. 2. Cluster analysis of the 64 sweet potato landraces based on Ward's method using discriminating qualitative variables

Table 4. Analysis of variance

Variation within groups	Degrees of freedom	Sum of squares	F value	Prop
G_1	6	146.30	20.09	0.00**
G_2	6	102.06	5.88	0.00**
G_3	6	7.23	0.75	0.60
G_4	6	303.60	51.38	0.00**
G_5	6	430.12	77.48	0.00**
G_6	6	176.00	63.27	0.08
G_7	6	46.89	5.84	0.00**

*** : significant at the 0.01 levels*

3.2 Variability between Sweet Potato Landraces Based on Quantitative Variables

Six (6) quantitative variables were evaluated. Table 5 presented a descriptive statistic and an analysis of variance of these variables. The results obtained showed that a highly significant difference (P <0.001) between landraces for these variables whose values varied within landraces. For example, the number of leaf lobe ranged from 1 to 9 with an average of 4.47, the petiole length from 3.4 cm to 22 cm with an average of 10.30 cm. Similarly, the internodes and main vine lengths varied respectively from 1.5 cm to 7.5 cm (3.80 cm on average) and 50 cm to 394 cm (166.85 cm on average). Mature leaf size varied between 4 cm and 15 cm with an average of 8.77 cm.

Table 5. Descriptive statistic and analysis of variance of quantitative variables

Variables	Min	Max	Average	SD	CV%	F	P
PL (cm)	3.40	22.00	10.30	3.92	38.07	90.24	< 0.001
NNL	1.00	9.00	4.47	1.70	38.09	421.52	< 0.001
VID (mm)	2.00	14.00	5.64	2.05	36.47	18.84	< 0.001
VIL (mm)	1.50	7.50	3.80	1.22	32.32	25.65	< 0.001
MVL (cm)	50.00	394.00	166.85	86.89	52.07	82.31	< 0.001
MLS (cm)	4.00	15.00	8.77	72.70	30.79	61.93	< 0.001

SD : Standard deviation; CV : coefficient of variation; PL : petiole lenght; NLL : number of leaf lobe; VID : Vine internode diameter; VIL : Vine internode lenght; MVL : Main vine lenght; MLS : Mature leaf size

The Principal Component Analysis (PCA) showed that the first two axes have a discriminatory variance of 61.93% of the information (Table 6). The first axis explains 39.10% of the total variability and is correlated with averages of petiole length, vine internode diameter, vine internode length, and mature leaf size. The second axis explains 21.83% of the total variability and is correlated with averages of the number of leaf lobes and main vine length. In total, the six qauntitative variables can be used to discriminate the landraces.

The correlations matrix between the quantitative variables showed the relationships that exist between the variables (Table 7). For example, the average petiole length is highly significant and positively correlated ($P < 0.05$; $r > 0$) with the averages of vine internode diameter, vine internode length, main vine lenght and mature leaf size. The average of number of leaf lobes is highly significant and negatively correlated ($P < 0.05$; $r < 0$) with the averages of vine internode diameter and main vine length.

The cluster analysis based on quantitative discriminant variables shows that the 64 landraces are classified into seven (7) groups (Fig. 3).

The analysis of variance performed with the means of the variables on the different groups of cluster analysis made it possible to identify the characteristics of each group (Table 7).

- Group 1 contained landraces with main vine are erect (64.50 ± 1.02 cm) and length and diameter of the internodes are respectively short (3.05 ± 0.19 cm) and thin (4.16 ± 0.18 mm). The petioles are very short and the size of the mature leaf is variable with small to medium.
- Group 2 included landraces with main vine are semi-erect (98.90 ± 2.23 cm) and length and diameter of the internodes are respectively short (3.63 ± 0.14 cm) and thin (5.45 ± 0.24 mm). Petiole length is very short and mature leaf size is variable, small to medium.
- Group 3 is formed by landraces with main vine are extremely spreading (354.66 ± 5.37 cm) and length and diameter of the internodes are respectively short (4.55 ± 0.32 cm) and intermediate (8.00 ± 0.76mm). The petioles are short and mature leaf size is medium.
- Group 4 included landraces with semi-erect main vine (142.50 ± 0.50 cm) and with length and diameter of the internodes are respectively very short (3.48 ± 0.16 cm) and thin (5.87 ± 0.32 mm). The petiole length is variable (very short to short) and mature leaf size is short.

Table 6. Principal component analysis showing the contribution of each axis

Variables	Axis 1	Axis 2	Axis 3
Petiole lenght (cm)	**0.59**	-0.33	0.28
Number of leaf lobes	-0.22	**-0.79**	0.39
Vine internode diameter (mm)	**0.73**	0.21	-0.10
Vine internode lenght (mm)	0.23	**-0.83**	-0.23
Main vine lenght (cm)	**0.83**	-0,09	-0.20
Mature leaf size (cm)	**0.56**	0.39	0.54
% Eigen values	39.10	22.83	12.93
Cumulative % Eigen values	39.10	61.93	74.86

Table 7. Pearson correlation coefficients between quantitative variables

	PL (cm)	NLL	VID (mm)	VIL (mm)	MVL (cm)	MLS (cm)
PL (cm)	1.00					
NLL	0.11ns	1,00				
VID (mm)	0.27**	-0.14**	1.00			
VIL (mm)	0.19**	-0.08ns	0.17**	1.00		
MVL (cm)	0.31**	-0.20**	0.39**	0.41**	1.00	
MLS (cm)	0.51**	0.12ns	0.32**	0.07ns	0.27**	1.00

*** : significant correlations marked at P < 0.05; PL : petiole lenght; NLL : Number of leaf lobe; VID : Vine internode diameter; VIL : Vine internode lenght; MVL : Main vine lenght; MLS : Mature leaf size*

Table 8. Characteristics of different groups of landraces based of quantitative variables

Variables	G1	G2	G3	G4	G5	G6	G7	F	P
PL (cm)	8.57 ± 0.41**a**	8.87 ± 0.49**a**	10.56 ± 0.80**a**	9.72 ± 0.58**a**	10.17 ± 0.53**a**	12.62 ± 0.94**a**	12.83 ± 1.14**a**	1.86	0.10**ns**
NLL	5.16 ± 0.29**a**	4.63 ± 0.20**a**	3.66 ± 0.45**a**	4.25 ± 0.35**a**	5.00 ± 0.29a	3.80 ± 0.37**a**	4.25 ± 0.29**a**	0.97	0.45**ns**
VID (mm)	4.16 ± 0.18**b**	5.45 ± 0.24**ab**	8.00 ± 0.76**a**	5.87 ± 0.32**ab**	6.00 ± 0.31**ab**	5.40 ± 0.17**ab**	6.00 ± 0.57**ab**	2.94	0.01*
VIL (cm)	3.05 ± 0.19**b**	3.63 ± 0.14**b**	4.55 ± 0.32**a**	3.48 ± 0.16**a**	3.80 ± 0.18**a**	4.29 ± 0.21**b**	4.47 ± 0.23**b**	2.33	0.04*
MVL (cm)	64.50 ± 1.02**g**	98.90 ± 2.23**f**	354.66 ± 5.37**a**	142.50 ± 0.50**e**	170.37 ± 1.63**d**	212.70 ± 2.12**c**	248.37 ± 2.47**b**	537.79	0.00***
MLS (cm)	7.80 ± 0.36**a**	8.07 ± 0.27**a**	10.10 ± 0.39**a**	7.40 ± 0.44**a**	10.27 ± 0.50**a**	9.90 ± 0.61**a**	8.61 ± 0.68**a**	1.80	0.11**ns**

** : significant correlations marked at P < 0.05; PL : petiole lenght; NLL : number of leaf lobe; VID : vine internode diameter; VIL : vine internode lenght; MVL : main vine lenght; MLS : mature leaf size*

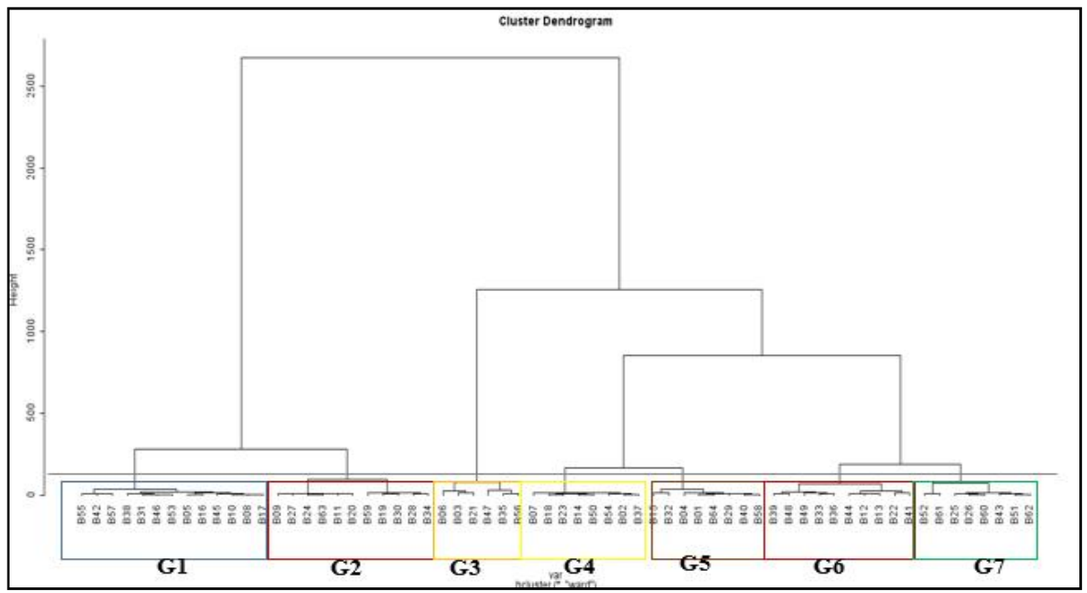

Fig. 3. Cluster analysis of the 64 sweet potato landraces based on Ward's method using discriminating quantitative variables

- Group 5 is formed by landraces with spreading main vine (170 ± 1.63 cm) and length and diameter of the internodes are respectively short (3.80 ± 0.18 cm) and intermediate (6.00 ± 0.31 mm). The petioles are short and the mature leaf size is medium.
- Group 6 contained landraces with more spreading main vine (212.70 ± 2.12 cm) and length and diameter of the internodes are respectively short (4.29 ± 0.21 cm) and intermediate (9.90 ± 0.61 mm). The petioles are short and the mature leaf size is medium.
- Group 7 included landraces with main vine are extremely spreading (248.37 ± 2.47 cm) and length and diameter of the internodes are respectively short (4.47 ± 0.23 cm) and intermediate (6.00 ± 0.57 mm). The petioles are shorter and the mature leaf size is medium.

4. DISCUSSION

The analysis of phenotypic evaluation results showed the existence of morphological variability within sixty-four sweet potato landraces. Indeed, thirteen (13) of the twenty-five (25) variables used were discriminant, including seven (7) qualitative and six (6) quantitative variables. Among the discriminant variables, predominant vine color, general appearance of leaf, predominant skin color of tubers, secondary flesh color of the tubers and main vine length were endogenous identification criteria used by the producers in the collection area [7]. Conversely, criteria such as the shape of tubers, the mature leaf color used by the producers for the identification of landraces did not show any significant differences. Therefore, their use did not really distinguish the varieties. Morphological characterisation of sweet potato in several West African countries has shown that other variables such as type of leaf lobe, the formation of tubers, the predominant flesh color of tubers were discriminating to differentiate sweet potato accessions [11,17,18]. Thus, environmental factors could influence the morphological features studied, which is shown by Agre et al. [14] on cassava in Benin. It is therefore necessary that this morphological characterisation be taken up in different zones in order to better appreciate the discriminating power of each morphological variable. The skin and flesh colors of tubers are also a criteria for the choice of landraces by the producers in the collection area. The phenotypic evaluation also has shown that sweet potato tubers with skin to white and cream are the most numerous and account for 53.12% of the collection, compared with 45.31% of the tubers with pink, red, purple red and dark purple. One landrace of sweet potato was also distinguished by the color of the skin and the flesh of the tubers. This is "Dokoui carotte" whose tubers are skinned and fleshed orange. Apart from this landrace, others such as ''Blè'', ''Bombo wéwe'', ''Bombo vovo'', ''Massawin'', ''Amitchéwin'' also have their colored flesh. These landraces could be potential sources of vitamin A and minerals and are to be valued to ensure food security and to combat children malnutrition in Benin [4,19]. The establishment of *in vitro* collection of these landraces as well as their *ex situ* preservation by *in vitro* culture techniques should be considered for their possible use in selection and breeding programs. Discriminant qualitative variables also allowed to classify different sweet potato landraces into seven (7) groups. Intra-group variance analysis showed that there is a significant difference at the 5% threshold within the groups G1, G2, G4, G5 and G7. This justifies the presence of variability within the landraces of each of these groups. On the other hand, there is no significant difference within groups G3 and G6. Similarly, cluster analysis made on the basis of qualitative discriminant data showed the existence in the G1, G2 and G6 groups of duplicates. This may suggest a phenotypic resemblance related to the effect of the environment or the effective presence of duplicates. In addition, a cross-analysis of each of the groups resulting from the qualitative and quantitative data showed the existence of landraces who are qualitatively identical but quantitatively different. Similarly, there exists landraces that are quantitatively identical but qualitatively different. These results could be explained by the fact that the variation of the qualitative and quantitative traits that have been observed is not only related to the expression of the genotype of the different landraces, but also to the interaction of the genotype with the environment in which these landraces are grown as shown in the work of Agre et al. [14] on cassava. Koussao et al. [18] on the agromorphological and molecular characterisation of 112 accessions of sweet potato in Burkina Faso also revealed that the phenotypic variance within the sweet potatoes of the studied collection is higher than the genotypic variance for several characters. This reveals that it would be difficult to classify landraces collected efficiently without resorting to other types of

characterisations that are complementary. Molecular genetic characterisation is therefore essential to better categorise landraces collected because molecular markers are not influenced by environmental factors [18,20]. Similarly, the introduction *in vitro* culture of some of these landraces is to be carried out in order to develop effective protocols for the production and preservation *in vitro* of these landraces to produce healthy planting material and to preserve them a loss.

5. CONCLUSION

Sixty-four (64) landraces from Benin were phenotypically assessed and classified into seven (7) groups based on both qualitative and quantitative variables. These revealed the existence of diversity within the collection studied and the presence of landraces with colored flesh of tubers that have nutritional interest. The landraces of the different groups derived from the qualitative data analysis are different from those of the groups resulting from the analysis of the quantitative data. Molecular evaluation of this diversity is therefore needed to improve the results of this phenotypic assessment for *ex situ* preservation for selection and breeding programs, given the influence the environment may have on descriptive morphological variables.

ACKNOWLEDGEMENTS

The authors thank Mrs HINSON Cyriaque, ATINDEHOU Rodrigue and SOHOUNHLOUE Brice for having authorized the installation of the tests at the experimental site of Agricultural School of Akodeha.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAO Statistical Databases. Food and agriculture organization of the United Nations; 2015.
   Available:http://faostat.fao.org
2. Mbithe MJ, Steven R, Agili S, Kivuva MB, Kioko WF, Kuria E. Morphological characterisation of selected Ugandan sweet potato (*Ipomoea batatas* L) varieties for food and feed. Journal of Phylogenetics and Evolutionary Biology. 2016;4:163.
3. Rukundo P, Shimelis H, Laing M, Gahakwa D. Storage root formation, dry matter synthesis, accumulation and genetics in sweetpotato. Australian Journal of Crop Science. 2013;7(13):2054.
4. Sanoussi A, Adjatin A, Dansi A, Adebowale A, Sanni L, Sanni A. Mineral Composition of Ten Elites Sweet Potato (*Ipomoea batatas* [L.] Lam.) Landraces of Benin. International Journal of Current Microbiology and Applied Science. 2016a; 5(1):103-115.
5. Reddy R, Soibam H, Ayam V, Panja P, Mitra S. Morphological characterization of sweet potato cultivars during growth, development and harvesting. Indian Journal of Agricultural Research. 2018; 52(1):46-50.
6. Adégbloba YP. Analyse de la filière patate douce au Bénin. PDRT/MAEP, Rapport Final. 2003;162.
7. Doussoh AM, Dangou JS, Houedjissin SS, Assogba AK, Ahanhanzo C. Analyse des connaissances endogènes et des déterminants de la production de la patate douce [*Ipomoea batatas* (L.)], une culture à haute valeur socioculturelle et économique au Bénin. International Journal of Biological and Chemical Sciences. 2016; 10(6):2596-2616.
8. Dansi A, Vodouhè R, Azokpota P, Yedomonhan H, Assogba P, Adjatin A, Loko Y, Dossou-Aminon I, Akpagana K. Diversity of the Neglected and Underutilized Crop Species of Importance in Benin. The Scientific World Journal. 2012;932-947.
9. Sanoussi A, Dansi A, Orobiyi A, Gbaguidi A, Agre A, Dossou-Aminon I, Sanni A. Ethnobotany, landraces diversity and potential vitamin A rich cultivars of sweet potato (*Ipomoea batatas* (L.] Lam.) in southern and central Benin. Genetic Resources and Crop Evolution. 2016b; 64(6):1431-1449.
10. Orobiyi A, Dansi A, Assogba P, Loko L, Dansi M, Vodouhè R, Akouègninou A, Sanni A. Chili (*Capsicum annuum* L.) in southern Benin : Production constraints, varietal diversity, preference criteria and participatory evaluation. International Research Journal of Agricultural Science and Soil Science. 2013;3(4):107-120.
11. Tairo F, Mneney E, Kullaya A. Morphological and agronomical characterization of sweet potato [*Ipomoea batatas* (L.) Lam.] germplasm collection

from Tanzania. African Journal of Plant Science. 2008;2(8):077-085.
12. Veasey EA, Silva JRDQ, Rosa MS, Borges A, Bressan EdA, Peroni N. Phenology and morphological diversity of sweet potato (*Ipomoea batatas*) landraces of the Vale do Ribeira. Scientia Agricola. 2007;64(4): 416-427.
13. Adoukonou-Sagbadja H, Missihoun AA, Sedah P, Dagba RA, Kinhoegbe G, Ahanhanzo C, Agbangla C. Variabilité génétique des accessions d'igname *Dioscorea alata* L. introduites au Bénin à partir des Îles du Sud-Pacifique. Journal of Applied Biosciences. 2014;73(1):5966-5978.
14. Agre A, Kouchade S, Odjo T, Dansi M, Nzobadila B, Assogba P, Dansi A, Akoegninou A, Sanni A. Diversité et évaluation participative des cultivars du manioc *(Manihot esculenta Crantz*) au Centre Bénin. International Journal of Biological and Chemical Sciences. 2015; 9(1):388-408.
15. Gnanglè CP, Glèlè Kakaï R, Assogbadjo AE, Vodounnon S, Afouda Yabi J, Sokpon N. Tendances climatiques passées, modélisation, perceptions et adaptations locales au Bénin. Climatologie. 2011;8:27-40.
16. CIP, AVRDC, IBPGR. Descriptors for sweet potato. Huamàn, Z., editor. International Board for Plant Genetic Resources, Rome, Italy. 1991;51.
17. Amoatey H, Sossah F, Ahiakpa J, Quartey E, Appiah A, Segbefia M. Phenotypic profiles of different accessions of sweet potato (*Ipomoea batatas* L. Lam) in the coastal savanna agro-ecological zone of Ghana. African Journal of Agricultural Research. 2016;11(26):2316-2328.
18. Koussao S, Gracen V, Asante I, Danquah EY, Ouedraogo JT, Baptiste TJ, Vianney T. Diversity analysis of sweet potato (*Ipomoea batatas* [L.] Lam) germplasm from Burkina Faso using morphological and simple sequence repeats markers. African Journal of Biotechnology. 2014; 13(6):729-742.
19. Sanoussi A, Dansi A, Bokossa-yaou I, Dansi M, Egounlety M. Formulation and biochemical characterization of sweet potato (*Ipomoea batatas*) based infant flours fortified with soybeanand sorghum flours. International Journal of Current Microbiology and Applied Science. 2013; 2(7):22-34.
20. Yada B, Tukamuhabwa P, Wanjala B, Kim DJ, Skilton RA, Alajo A, Mwanga RO. Characterization of Ugandan sweetpotato germplasm using fluorescent labeled simple sequence repeat markers. HortScience. 2010;45(2):225-230.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26046