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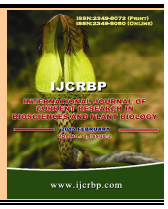

Original Research Article

Agromorphological Characterization of Elite Cassava (*Manihot esculenta* Crantz) Cultivars Collected in Benin

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Abstract

Cassava (*Manihot esculenta* Crantz) is an important storage root crop with largely unexplored and unexplained potentially valuable genetic variability in Benin. Genetic variability is important in selecting suitable genotypes for crop improvement. The present study was aimed at assessing the extent of genetic variability and diversity of elite cassava collected in Benin, based on 41 qualitative and quantitative traits. One hundred and sixteen (116) cassava genotypes were evaluated in a randomized complete block design in Central Benin. Data assessment was done three, six, nine and twelve months after planting. For the quantitative parameters, high variability was found for the plant height, root length, number of the root per plant, petiole length, lobe length and lobe width. Positive correlation was found between the fresh root weight and the number of root per plant, root length and stem diameter. Principal Component Analyze (PCA) clustered the total varieties into 4 groups with special characteristics. Estimates of variance components revealed that a large portion of the phenotypic variance was accounted for the genotypic component for all traits assessed indicating substantial genetic variability among the genotypes evaluated. This genetic variability is important in a hybridization and/or selection program because it implies that significant genetic gain through phenotypic selection is possible for the traits assessed. The information generated will inform future breeding initiatives to develop early-bulking high yield cassava genotypes with farmer-preferred traits in Benin.

Keywords

Agro-morphological characterization
Benin
Elite cassava
Genotypic variation
Quantitative traits

Introduction

Cassava (*Manihot esculenta* Crantz), currently is the fifth most important world food crop (FAO, 2013). Cassava has an edible starchy root tuber, which provides more than half of the calories consumed by more than 800 million people in Sub-Saharan Africa (SSA), Latin America and Asia (Kumba et al., 2012). It has become the most important source of dietary energy in SSA (Dixon et al., 2002; Raji et al., 2007) as it provides more dietary energy per hectare and working hours than any other staple crop (Fregene et al., 2000; Nassar, 2006; Mamba-Mbayi et al., 2014). The main nutritional component of cassava is carbohydrate, which is derived from starch accumulated in its tuberous storage roots. The storage roots also contain small amounts of proteins ranging from 1-2% on fresh weight basis. The leaves and tender shoots are consumed as vegetable in many parts of Africa and are a cheap but rich source of proteins and vitamins. Cassava's advantage over other food crops includes flexibility in planting time, harvesting time, and its drought tolerance ability (Kombo et al., 2012; Robooni et al., 2014). Moreover, it is also able to grow and produce on low nutrient soils, where cereals and other crops do not grow well, and is well suited for incorporation in various cropping systems (Nassar, 2006; Kumba et al., 2012).

In Benin, cassava is grown across all agro-ecological zones but at different frequencies and ranks second position after maize in terms of area and production in tons. In Benin, these crops are consumed by more than 70% of the population in different ways as raw or after processing into gari, chips, tapioca, etc. indicating its importance as food security crop. However, the average crop yield in Benin is still as low as 8 tonnes per hectare (MAEP, 2013). The low yield of the crop is attributed to many factors including the use by farmers of unimproved planting materials, the lack of good agronomic practices and lack of knowledge in control of pests and diseases. Although cassava is well integrated into the diverse traditional farming systems, very little genetic improvement has been achieved because cassava planting materials have been selected and distributed by subsistence farmers (MAEP, 2013). Farmers have selected genotypes that best fit their needs and thus generate a large number of traditional varieties. In addition, different ethnic groups have contributed to selection, thus leading to numerous vernacular names to the same varieties according to ethnic groups (Agre et al., 2015). In Benin, cassava varieties are grown mainly by small-scale farmers who observe, select and name their cassava varieties based on morphology, food, social and economic interest. This nomenclature has led to confusion in the exact numbers and identity of cassava cultivars under cultivation in Benin. There is the need to characterize the cassava elite collected throughout Benin to remove possible duplicates, establish the diversity of the cassava cultivars to enhance genetic improvement of the crop and to find out the best cassava cultivars with high yield.

Materials and methods

Vegetative material

One hundred and sixteen (116) accessions of elite cultivars (cultivated by many households on large areas) were collected April to May 2013 from major cassava growing regions of Benin (Southern and Central Region and in Atacora Department) (Table 1). In these regions, farmers practice traditional farming where stem cuttings are replanted after harvest or are obtained from relatives' and neighbours' fields or from abandoned fields (Agre et al., 2015). Cassava planting stakes of 20-30 cm in length from the 116accessions obtained from farmers were planted in May, 2013, with three mounds per plants for each cultivar in a Randomised Complete Block Design (RCBD) in the open field at the Faculty of Sciences and Technology of Dassa (Central Benin). The distance used between plants was 1 meter. Manual weeding was done at needed time. No fertilizer was applied. Harvesting was done 12 month after planting.

Data collecting

Characterization of the varieties was based on both qualitative (Table 2) and quantitative (Table 3) data for agro-morphological traits. According to Fukuda et al., (2010) the data were recorded at 3, 6 and 9 months after planting and at harvest time. For qualitative data, special scores or scales were used to record the data (Table 3).

Table 1. Different cassava elite cultivars studied and their collection sites.

N°	Vernacular names	Sites	Districts	Regions
1	Abidjan	Idadjo	Ouesse	Central
2	Abohoungo	Akomya	Glazoue	Central
3	Aboidassa	Omou	Ketou	Southern
4	Adja	Yagbo	Glazoue	Central
5	Adjagounfounfoun	Betecoucou	Dassa	Central
6	AdjagounNigeria	Oke-Owo	Glazoue	Central
7	Adjatin Daho	Dame-Wogon	ze	Southern
8	Affodjouba	Omou	Ketou	Southern
9	Agbahizi	Gbakpodji	Bopa	Southern
10	Agbakomessi	Oko-Akare	Kpobe	Southern
11	Agbeyido	Gbakpodji	Bopa	Southern
12	Agoula	Atchonssa	Bonou	Southern
13	Agrik Blanc	Gbehoue	Grand-Popo	Southern
14	Agrik Rouge	Gbehoue	Grand-Popo	Southern
15	AhossouFaingnin	Abesouhoue	Glazoue	Central
16	AhotononFita	Fita	Dassa	Central
17	Ahotonon non toxique	Lama	Savalou	Central
18	Akparokoffo rouge	Miniki	Savalou	Central
19	Akpave	Gbehoue	Grand-Popo	Southern
20	Alexifaingnin	Lama	Savalou	Central
21	Analo Bara	Datori	Cobli	Northern
22	AnaloBiesso	Datori	Cobli	Northern
23	Antiota	Danhoue	Gbegon	Southern
24	Assomanzrewewe	Miniki	Savalou	Centrale
25	Atinwe	Akpadanou	Bonou	Southern
26	Atinwi	Fita	Dassa	Centrale
27	Avion de terre	Aglamidjodji	Savalou	Centrale
28	Awilivou	Ouedo	Abomey-Calavi	Southern
29	Awonlifaingnin	AyouTokpa	Allada	Southern
30	Awoubi-elou	Gbere	Save	Central
31	Azanminwe	Aidjedo	Kpomasse	Southern
32	Baba robert	Idadjo	Ouesse	Central
33	Bamsigni	Oke-Owo	Glazoue	Central
34	Bassia	Akpadanou	Adjohoun	Southern
35	Batchego	Goutin	Adjohoun	Southern
36	Bawe	Akpadanou	Bonou	Southern
37	BEN	Assaba	Bante	Central
38	Bioba	Gbadavo	Dassa	Central
39	Blanwidji	Gbede	Save	Central
40	Bobirin	Omou	Ketou	Southern
41	Briguede	Affizoungo	Glazoue	Central
42	Carder blanc	Akomiya	Glazoue	Central
43	Carder Rouge	Akomiya	Glazoue	Central
44	Cooco	Sowe	Glazoue	Central
45	Dadjofolligbesse	Itadjebou	Sakete	Southern
46	Dagui-Dagui	Omou	Ketou	Southern
47	Danadanan	Okemere	Glazoue	Central
48	Dawe	Goutin	Adjohoun	Southern
49	Djabadjaba	Aglamidjodji	Savalou	Central
50	Dokouin	Lama	Savalou	Central
51	Eyekoffo	Omou	Ketou	Southern
52	FaingnintiVeve	Gbekandji	Adjohoun	Southern
53	Faingnintinwewe	Dawe-centre	Ze	Southern
54	Fainto	Gbeze	Aplahoue	Southern

N°	Vernacular names	Sites	Districts	Regions
55	Fekevovo	Yokpodjevie	Ze	Southern
56	Fofovi	Gnokpongnon	Dassa	Central
57	Foudikpo	Okemere	Glazoue	Central
58	Gbakaya	Danhoue	Houeyogbe	Southern
59	Gbaze	Dedekpoue	Athieme	Southern
60	Glegbodji	Glegbodji	Abomey-Calavi	Southern
61	Globo	Kokohoue	Djakotome	Southern
62	GohotoFaingnin	Lama	Savalou	Central
63	Goro	Fita	Glazoue	Central
64	Hewado	Akpadanou	Adjohoun	Southern
65	Hollegoumin	Aidjedo	Kpomasse	Southern
66	Holly faingnin	Agao	Glazoue	Central
67	Hombete	Agbodji	Bopa	Southern
68	Houlameguegue	Yagbo	Glazoue	Central
69	HoulameKloklo	Yagbo	Glazoue	Central
70	Ibecher	Omou	Ketou	Southern
71	Idilerou Centre	Betecoucou	Dassa	Central
72	IdilerouSud	Omou	Ketou	Southern
73	Israel	Idadjo	Ouesse	Central
74	Kintogbadji	Lokogba	Lalo	Southern
75	Koffeorogou	Omou	Ketou	Southern
76	Komina	Tchakalakou	Toukoutounan	Northern
77	Koukpabiekpo	Assaba	Bante	Central
78	Koutewe	Hekanme centre	Ze	Southern
79	Kpassa	Abessouhoue	Glazoue	Central
80	Kpeke	Yokpodjevie	Ze	Southern
81	Kpessimon	Gbede	Save	Central
82	Kpokpoiriko	Omou	Ketou	Southern
83	Krokotoya	Tchakalakou	Toukoutounan	Northern
84	Lelibovovo	Gbedavo	Dassa	Central
85	Lelibowewe	Gbedavo	Dassa	Central
86	Loki Petiole Blanc	Banon	Bante	Central
87	Loki Petiole rouge	Banon	Bante	Central
88	Malebra	Banon	Save	Central
89	Mamboussa	Assaba	Bante	Central
90	Martin	Idadjo	Ouesse	Central
91	Monlekangan	Assaba	Bante	Central
92	Obassandjo	Ikpedjile	Sakete	Southern
93	Odohoungbo	Okomere	Okemere	Central
94	Offegue	Fita	Dassa	Central
95	OkaiyawoSud	Dame-Wogon	Bonou	Southern
96	Okin petiole blanc	Omou	Ketou	Southern
97	OkinPetiole rouge	Ikedjile	Sakete	Southern
98	Okoiyawofounfoun	Banon	Bante	Central
99	Okoiyawodoundoun	Banon	Bante	Central
100	Okoognibo	Banon	Bante	Central
101	Okpadoundoun	Oke-Owo	Glazoue	Central
102	Oligbesse	Gnonkpingnon	Dassa	Central
103	Olowo-oke	Gbere	Save	Central
104	Otegbeye	Ikpedjile	Sakete	Southern
105	Oueminnou	Agbodji	Bopa	Southern
106	RB 1	Ewe	Ketou	Southern
107	RB 2	Ewe	Ketou	Southern
108	Sammi	Igbo Ede	Ketou	Southern
109	Sodaf	Gledbodji	Abomey-Calavi	Southern

N°	Vernacular names	Sites	Districts	Regions
110	Soukounon	Yagbo	Glazoue	Central
111	Sowe	Vedji	Dassa	Central
112	Tatawili	Assaba	Bante	Central
113	Tchowoyekete	Omou	Ketou	Southern
114	TMS	Assaba	Bante	Central
115	Vobodouaho	Ouedo	Abomey-Calavi	Southern
116	Yeke	Tchakalakou	Toukoutounan	Northern

Table 2. Qualitative data used, collecting period and score affected.

Period of data recording	Type of variable	Code	Scoring
Three months after planting	Color of apical leaves	CAL	(3) Light green; (5) Dark green; (7) Purplish green; (9) Purple; (11) Others
	Pubescence of apical leaves	PAL	(0)Absent; (1) Present
Six months after planting	Lobe margins	LoM	(3) Smooth; (7) Winding
	Color of leaf vein	CLV	(3) Green; (5) Green-reddish; (7) Red
	Petiole colour	PeC	(1) Green-yellowish; (2) Green; (3) Green-reddish; (5) Red-green; (7) Red; (9) Purple
	Flowering	Flo	(0)Absent ; (1) Present
	Shape of central leaflet	SCL	(1) Ovoid ; (2) Elliptic-lanceolate ; (3) Obovate-lanceolate; (4) Rectangular-lanceolate; (5) Lanceolate; (6) Straight or linear; (7) Other
	Orientation of petiole	OPe	(1) Downwards; (3)Horizontal; (5) Upwards ; (7) Irregular
	Pollen	Pol	(0)Absent; (1) Present
	Leaf retention	LRe	(1)Very poor retention; (2) Less than average retention; (3) average; (4) Better than average retention
Nine months after planting	Stipule margin	StM	(1) Entire; (2) Split
	Color of stem epidermis	CSE	(1) Creme; (2) Light brown; (3) Dark brown; (4) Orange
	Color of end branches	CEB	(3) Green; (5) Green-purple; (7) Purple
	Color of stem cortex	CSC	(1) Orange ; (2) Light green ; (3) Green
	Color of stem exterior	CSEx	(1) Orange; (2) Light brown; (3) Dark brown; (4) Yellow; (5) Golden; (6) Argente; (7) White; (8) Red; (9) Dark
	Growth habit of stem	GHS	(1) Straight; (2) Zig zag
	Distance between leaf scar	DLS	(3) Short; (5) Medium; (7) Long
	Importance of foliar scar	IFS	(3) Less important; (5) Important
	Length of stipules	LSt	(3)Long; (5) Short
	Branching habit	BrH	(1)Erect; (2) Dichotomous; (3)Trichotomous; (4)Tetrachotomous
Twelve months after planting	Root constrictions	RCo	(1)Few or none; (2) Some; (3) Many
	Color of root cortex	CRC	(1)White or creme; (2) Yellow; (3) Pink; (4) Purple;
	Color of root pulp	CRP	(1)White; (2) Creme; (3) Yellow; (5) Pink
	External colour of storage root	ECR	(1)Creme or white; (2) Yellow; (3) Light brown; (4) Dark brown
	Extent of root peduncle	ERP	(0)Sessile; (3) Pedoncule; (5) Mix
	Shape of plant	SP	(1) Compact; (2) Open; (3) Umbrella; (4) Cylindrical
	Root shape	RS	(1) Conical; (2) Conical –cylindrical; (3) Cylindrical; (5) Irregular
	Texture of root epidermis	TRE	(3) Smooth; (5) Intermediate; (7) Rough

Table 3. Quantitative data used and technique of measurement.

Period of data recording	Data	Codes	Techniques of measurement
6 months after planting	Width of leaf lobe	WLL	Two leaves from the middle of the plantmeasured from the widest part of the middle lobe.
	Length of leaf lobe	LLL	Measured from the intersection of all lobes to the end of the middle lobe.
	Petiole length	PLe	Measured on two leaves per plant.
	Number of leaf lobes	NLL	Counted on five leaves per plant with consideration of the predominant number of lobes
	Ratio length/width lobe	RL/W	Ratio between length and width was performed with Excel
12 months after planting	Diameter of root	DR	Three root were considered and the diameters were taken in the medium of the root
	Diameter of Stem	DSt	Taken on two stems per cultivar
	Height to first branching	HFB	Measured vertically from ground to first primary branch.
	Plant height	PH	Measured vertically from the ground to the top of the canopy.
	Length of root	LR	Recorded on roots with length greater than 20 cm from three plants
	Number of roots per plant	NRP	Number of roots with length greater than 20 cm from three plants
	Weight of fresh root	WFR	All the root shaving length greater than 20 cm are weighted

Statistical analysis

For quantitative data, descriptive statistics and correlation coefficients analysis were computed using Statistica (version 7.1) software. Factor analysis was performed to determine which trait contributed the highest variability. Principal component analysis was used to examine the contribution of each trait to total genetic variation using Minitab 14 and Statistica software. Multiple Component Analysis was done on qualitative data and the variables that presented the highest variability were used to construct dendrogram with NTSYS p.c. 2.2 computer package (Rohlf, 2000) and the Unweighted Pair Group Method of Arithmetic Averages (UPGMA) in SAHN clustering program (Rohlf, 2000).

Results and discussion

Variability between the cassava elite cultivars based on qualitative data

Multiple component analysis of the qualitative data showed that 7 factors counted for 63.55% (Table 4). The first component counted for 15.12% and the color of apical leave, petiole color, vein color, type of root, external color of stem, root extent and the color of terminal branching were correlated with this axe (Table 4). The second factor counted for 11.31% and the flowering, presence of pollen in the flower, stipule lobe and stipule margin were the principal parameters correlated with the second factor. Constriction of the root, plant type, the color of the terminal branching and external color of the root which was the principal parameters correlated with the 3 factors and counted for 10.15%. In total, 17 qualitative traits among the 29 used showed high variability and were considered as the most important to be used to describe cassava germplasm. Similar results were obtained in Colombia in the characterization of the cassava core collection (Okogbenin et al., 2001). Kumba et al. (2012) found similar results in a similar study of the core collection of Ghana cassava germplasm.

Cluster analysis of the 116 elite cassava cultivars revealed six major clusters (Fig. 1) named C1 to C6.

- C1 contains the majority of the elite cassava cultivars and is partitioned into 4 sub-clusters (Fig. 1). Sub-cluster 1-a grouped cassava cultivars that have green petiole, dark green young leaves, irregular root shape and rough root epidermis. Sub cluster

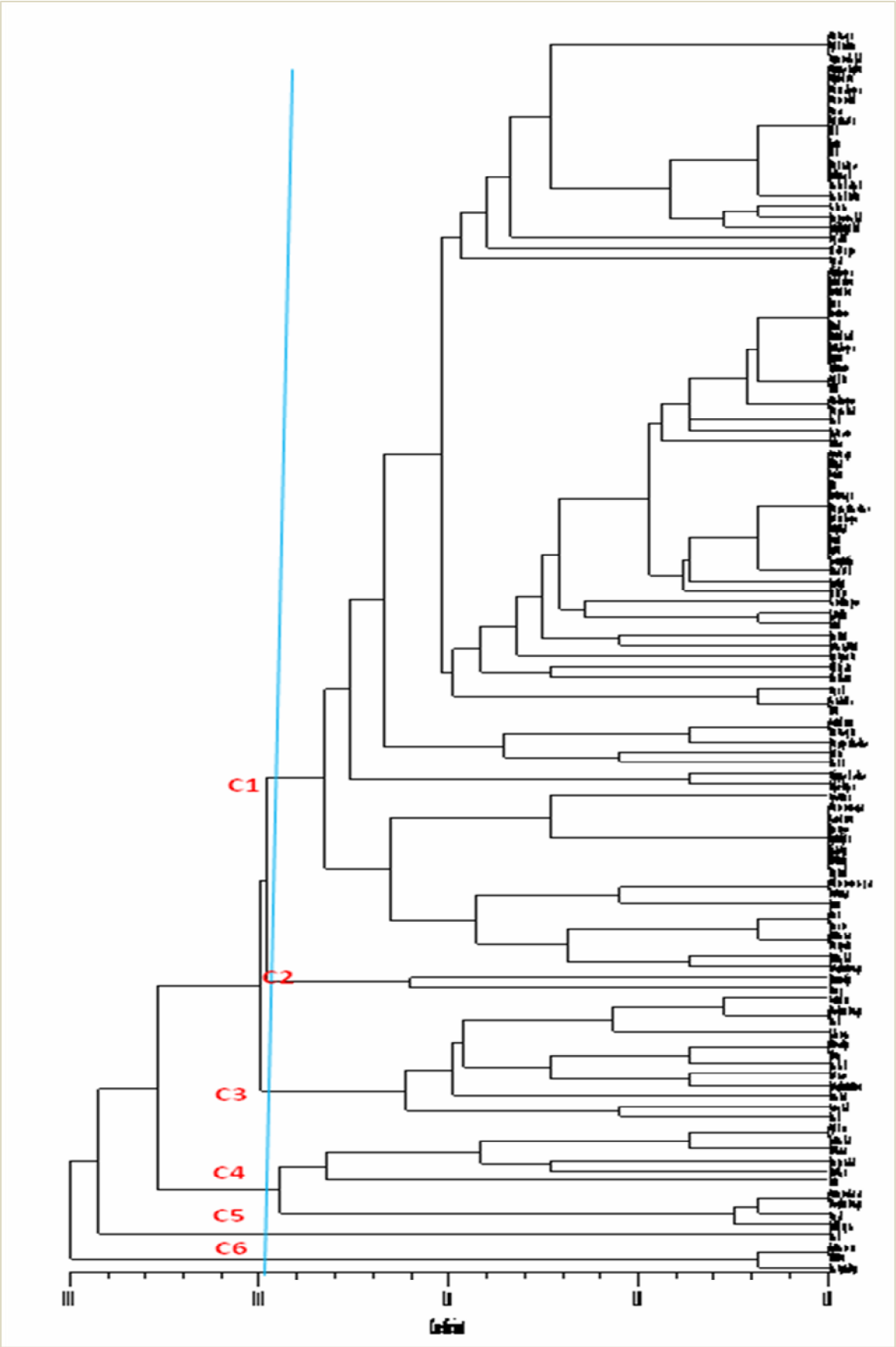
1-b associated cultivars with smooth root texture and mixed peduncle; Sub-cluster 1-c grouped cultivars with green petiole and high leaf retention.

- Cluster 2 contained only two cultivars (Fig. 1) with green apical leaves, purple petioles and straight growth habit. They appear unique from the total varieties analyzed.
- Cluster 3 gathered 13 cultivars with yellow stems and purple youth leaves.
- Cluster 4 grouped some cultivars with red stems, dark brown storage root and the cultivars of this group were presented to have three branches at the first branching "trichotomous varieties"
- Only cultivar "Dawe" constituted the cluster 5. It has red colored stem, green apical leaves and green petiole.
- Cluster 6 grouped three varieties characterized by red stem and red petiole.

Table 4. Multiple Component Analysis (MCA).

N°	Variables	Fact. 1	Fact. 2	Fact. 3	Fact. 4	Fact. 5	Fact. 6	Fact. 7
1	**CAL**	**0.50****	-0.10	-0.02	0.30	-0.12	-0.13	-0.10
2	**PAL**	-0.29	-0.07	0.03	-0.12	-0.05	-0.16	**0.53****
3	FLC	0.24	0.26	-0.15	0.13	-0.42	-0.03	-0.27
4	**LRe**	0.03	0.27	0.36	**0.50****	0.09	0.18	-0.42
5	**PeC**	**0.57****	-0.05	-0.16	0.12	0.36	-0.12	-0.23
6	CoF	-0.38	0.43	0.03	-0.24	-0.12	-0.41	-0.09
7	**CLV**	**0.61****	-0.05	-0.09	-0.12	0.47	0.18	-0.40
8	OPe	-0.38	-0.14	0.17	-0.46	0.24	0.25	-0.02
9	**Flo**	-0.03	**-0.70****	0.27	**0.51****	-0.12	0.15	0.06
10	**Pol**	-0.03	**-0.70****	0.27	0.51**	-0.12	0.15	0.06
11	ALF	0.48	-0.15	-0.02	0.01	-0.41	-0.04	0.46
12	IFS	-0.47	0.24	0.12	0.03	0.01	0.68	0.18
13	CSC	0.23	-0.35	0.12	-0.65**	-0.08	0.18	-0.15
14	**CSE**	**-0.60****	0.08	0.10	0.23	-0.03	-0.51**	-0.27
15	**CSEx**	**0.70****	0.01	0.14	-0.07	0.02	0.24	-0.01
16	DLS	0.10	-0.44	-0.31	-0.34	0.07	-0.45	-0.08
17	GHS	0.13	0.01	0.08	-0.06	0.38	-0.35	0.29
18	**CEB**	**0.67****	-0.21	**-0.58****	0.10	0.07	0.05	0.02
19	**LSt**	-0.34	**-0.78****	-0.01	-0.28	0.01	0.07	-0.13
20	**StM**	0.28	**0.83****	0.07	0.25	-0.07	0.02	0.15
21	RaT	-0.43	-0.21	-0.28	0.28	-0.07	0.13	0.08
22	**RCo**	0.01	0.17	**-0.74****	0.00	0.30	0.23	0.14
23	**ERP**	**0.50****	-0.16	-0.44	0.12	-0.29	-0.16	0.27
24	RS	-0.02	-0.03	0.08	-0.17	0.03	-0.04	-0.21
25	**ECR**	**-0.51****	-0.07	**-0.73****	0.24	0.07	0.05	-0.12
26	Cep	0.06	-0.16	0.45	0.27	0.44	-0.27	0.21
27	CoC	-0.09	-0.14	0.04	0.33	0.69	-0.18	0.11
28	**BrH**	**-0.51****	-0.03	**-0.72****	0.21	0.06	0.06	-0.08
29	SP	0.03	0.23	0.00	-0.10	0.45	0.19	0.41
Proportion		**15,12**	**11.31**	**10.15**	**8.10**	**7.05**	**6.16**	**5.64**
Eigen value		**4,38**	**7.66**	**10.61**	**12.96**	**15.00**	**16.79**	**18.43**
% cumulated		**15,12**	**26.43**	**36.58**	**44.69**	**51.75**	**57.91**	**63.55**

Fig. 1: Dendrogram of 116 elite cassava cultivars based on qualitative data and UPGMA clustering method.



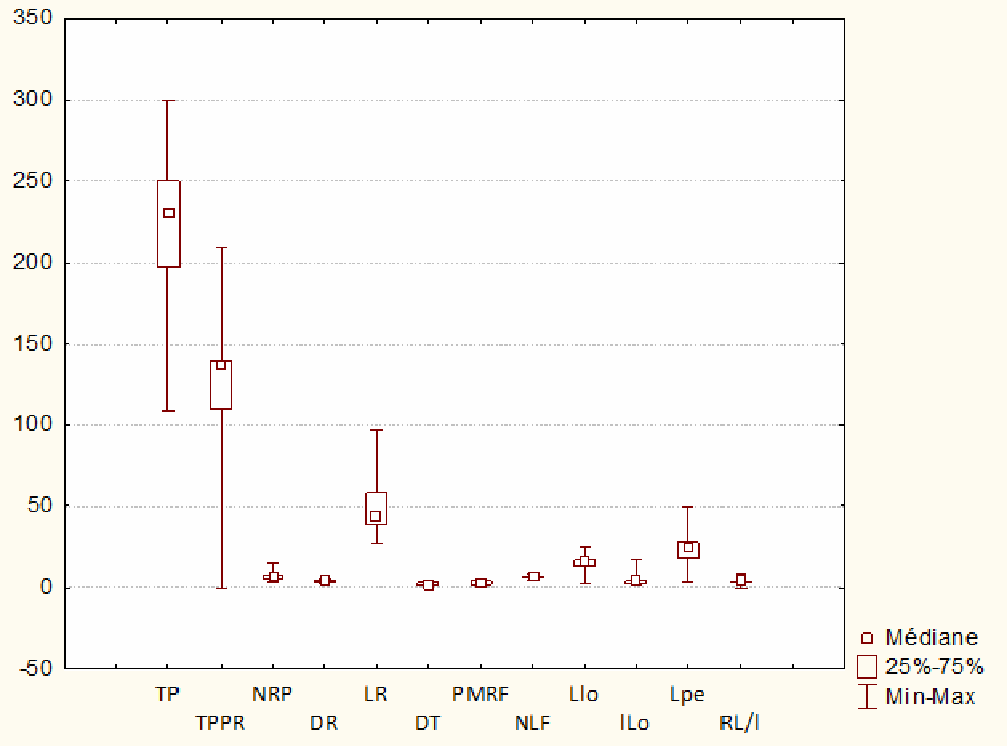
Agromorphological analysis based on quantitative data

All the quantitative traits recorded were subjected to descriptive statistics analysis (minimum, maximum, average, variance, standard deviation and coefficient of variation) to appreciate the variability of each trait among the cassava varieties (Table 5; Fig. 2). The cassava accessions showed variability for the twelve quantitative morphological traits assessed. The range of values produced were 109 to 300 cm for plant height, 4 to 16 for the number of fresh roots per plant, 2.90 to 6 cm for the diameter of root, 28 to 97 for the root length, 4.30 to 49 for petiole length and 0.7 to 5.8 (kg) for the weight of fresh root (Table 5). The coefficients of variation varied from 8.1% (number of leaf lobe) to 39.87% (width of lobe - NIP). Based on the 12 quantitative characters, 9 had high (CV> 20%) coefficients of variation (Table 5). Only three parameters have low variations. These are number of lobes per leaves (8.1%), height of the plant (15.47%) and the root diameter (14.79%). The high coefficients of variation observed for most (75%) of the studied traits indicated the presence of a high heterogeneity within the population characterized that can be exploited for breeding. These results are similar to those reported in India by Raghu et al. (2007), in Ghana by Kumba et al. (2012).

Table 5. Descriptive statistics of quantitative data.

Variables	Average	Min	Max	Variance	StDev	CoefV
PH	222.61	109	300	1186.18	34.44	15.47
FB	125.22	0	210	1807.13	42.51	33.95
NR	7.21	4	16	3.44	1.85	25.71
DR	4.32	2.9	6	0.41	0.64	14.79
RL	48.61	28	97	154.29	12.44	25.55
SD	2.74	1.49	4.6	0.937	0.93	35.27
FRW	3.52	0.7	5.8	1.7	1.7	37
Nlo	7.14	5	9	0.33	0.33	8.1
LoL	16.21	2.8	25.66	11.42	11.42	20.85
WLL	4.11	1.8	18	2.69	2.6	39.87
PL	24.39	4.3	49	56.03	56.06	30.68
RL/W	4.18	0.15	8.57	0.85	0.8	22.16

Fig. 2: Moustache box showing variability within quantitative trait.



The correlation matrices between quantitative variables (Table 6) established indicated that the plant height (PH) is the principal trait that is significantly and positively correlated with the first plant branching (FB), the number of roots per plant (NRP), the fresh root weigh (FRW), the stem diameter (SD), the number of leaf lobes (NLL). It is also noted that the fresh root weigh (FRW) is significantly correlated with the number of roots per plant (NRP), the root length (RL), root diameter (RD) and the stem diameter (SD). The correlation data constitutes an essential tool in the choice of characters to be integrated in cassava breeding programs. The results of this study corroborate those obtained on cassava in Ghana (Acquah et al., 2011; Kumba et al., 2012), in Colombia (CIAT, 2001) and in India (Rhagu et al., 2007; Lekka et al., 2011).

Table 6: Correlation matrix between quantitative variables.

	PH	FB	NRP	RD	RL	SD	FRW	NLL	LoL	LoW	PL
PH	1										
FB	0.41**	1									
NRP	0.19**	0.16	1								
RD	0.44**	-0.01	0.24**	1							
RL	0.21**	-0.43**	-0.06	0.50**	1						
SD	0.51**	0.14	0.22**	0.40**	0.35**	1					
FRW	0.16	-0.15	0.44**	0.39**	0.29**	0.63**	1				
NLF	0.18**	-0.15	-0.14	0.1	0.12	0.33**	0.23**	1			
Llo	0.33**	0.06	0.09	0.03	0	-0.16	-0.01	0.03	1		
LLo	-0.05	-0.05	-0.08	0	-0.08	-0.15	-0.06	-0.09	0.16	1	
Lpe	0.07	0.01	-0.01	0	-0.04	-0.06	0.18	0.20**	0.61**	0.28**	1
RL/l	-0.16	-0.12	0.02	-0.09	0.02	0	-0.01	0.14	0.13	-0.65**	0.07

** Significant value at $p<0.05$.

The principal component analysis grouped the 12 quantitative variables into various components with the first five axes explaining 76.19% of the total variation (Table 7). With Statistica software, variables with values more than 50% are correlated with the axe. Principal component 1 (PC1) associated with plant height (PH), root diameter (RD), stem diameter and fresh root weight (FRW) accounted for 23.55% of the total variation (Table 7). PC2 associated with the central leaf lobe length (LLL), width of the lobe (WL) and petiole length accounted for 15.93% of the total variability (Table 7). The height of the plant at the first branching, the petiole length and the length of the central lobe leaf and the ratio length per the width are those mostly correlated to the third axis accounting for 13.77%.

The height of the plant at the first branching, the width of the lobe and ratio length per width are the three parameters which are correlated with the fourth axis accounting for 13.26%. On the fifth axes, the number of roots per plant is the only one parameter correlated with. In total, eleven of the twelve quantitative parameters presented high variability and only the number of the lobe per leaf is not correlated with a given any of the five axes (Table 7).

For the total cultivars analyzed and based on the PC1 and PC2, the varieties studied were classified into four agromorphological classes with different characteristics named C1, C2, C3 and C4 (Table 8, Fig. 3). The comparison of the means of the different groups for each parameter revealed significant differences (p <0.05) between classes for eleven parameters out of the 12 considered (Table 8). The performances of the different groups are identified and summarized (Table 8). C1 for example grouped together some late maturing cultivars with high yield per hectare, many roots per plant and tall plants. Cultivars of these groups may be directly used for the breeding program trials. Moreover, individual plants belonging to the groups having interesting and complementary characters may serve as basis for crossing with the objective of developing novel or new varieties.

These results are similar to those obtained from yam (Malapa et al., 2003), sweet potato (Tairo et al., 2008; Norman et al., 2014) and on Taro (Garcia et al., 2004). The overall results indicated the existence of significant morphological diversity within the population studied. The molecular characterization of the studied collection with the SSR markers will probably help to better understand

the genetic structure of the cassava diversity in Benin.

Classical breeding uses morphological traits of plants growing in the field as basis for identification (Fukuda et al., 2010; Robooni et al., 2014). It has been effectively used as a powerful tool in the classification of cultivars and the study of their taxonomic status (Elisabeth, 2011). The certification of new cultivars or varieties is usually based on the genetic purity of a particular crop. However, traditionally, these assessments depend on botanical traits for cultivar identification. Breeders and geneticists have used morphological characteristics such as leaf and flower attributes to follow segregation of genes and hybrids, but most agronomic traits are not associated with easily observable phenotypic markers (Rabbi et al., 2014). Most of the descriptors are ambiguous and have limited use (Fregene et al., 2007). Such traits are controlled by multiple genes and are subject to varying degrees of environmental modification and interactions.

Table 7. Importance of variables on the factorials axes.

Variables	Fact. 1	Fact. 2	Fact. 3	Fact. 4	Fact. 5
Hpl	0.65**	0.38	-0.21	0.25	0.42
Hplr	0.03	0.40	-0.55**	0.58**	0.24
Nra	0.41	0.11	-0.27	0.30	-0.70**
Dra	0.72**	0.02	-0.11	-0.20	0.01
Lra	0.56**	-0.27	0.24	-0.45	0.11
Dti	0.82**	-0.15	-0.18	0.04	0.14
Pmra	0.74**	-0.06	0.08	-0.10	-0.44
Nlof	0.37	-0.08	0.44	-0.01	0.43
Llo	0.10	0.68**	0.51**	0.25	-0.04
llo	-0.15	0.65**	-0.11	-0.63**	-0.07
Lpe	0.11	0.64**	0.61**	0.06	-0.12
RL/l	0.01	-0.45	0.54**	0.61**	-0.07
Eigen value	**2.83**	**1.91**	**1.65**	**1.59**	**1.16**
Proportion	**23.55**	**15.93**	**13.77**	**13.26**	**9.67**
Cumulated	**23.55**	**39.48**	**53.26**	**66.52**	**76.19**
** correlated variables.					

Morphological characterization has been used to identify duplicates, study genetic variation patterns and correlation with characteristics of agronomic importance. Dixon et al. (2002); Noerwijati et al. (2013) reported that the variation in traits observed do not reflect only the genetic constitution of the cultivar, but also the interaction of the genotype with the environment (G × E) within which it is expressed. In cassava breeding programs emphasis has been on the collection and conservation of gene pools for characterization. A set of relatively stable morphological traits useful for characterization of cassava cultivars has been identified by IBPGR. The descriptors include qualitative and quantitative traits for cassava roots and shoot characters. Morphological characters have been mainly used to classify the *Manihot* species (Elias et al., 2001). Due to the influence of different ecological environments on cassava morphology, morphological classification based on variable traits is complex. These descriptors measure traits of the shoot and root which include: colors of unexpanded apical leaves, mature leaf color, tip shoot color, height at first branching, length of petiole, stem color, petiole color, leaf shape, root shape, rind and pulp color and many more (Nassar, 2006; Amenorpe et al., 2006). There is extensive diversity for most characters assessed. They are either monogenic or polygenic traits (constant or variable respectively). The variable traits are associated with gene and environment interaction. Robooni et al., (2014) have used morphological descriptors in cassava to access diversity among the *Manihot* species and within populations. It is reported that the phenotypic variance in cassava is higher than genotypic variance for traits of agronomic importance like tuberous root weight (Mathura et al., 1989). Reports from several studies have suggested the use of markers that are not environmentally influenced.

Fig. 3: Principal Component Analysis (ACP) based on quantitative data.

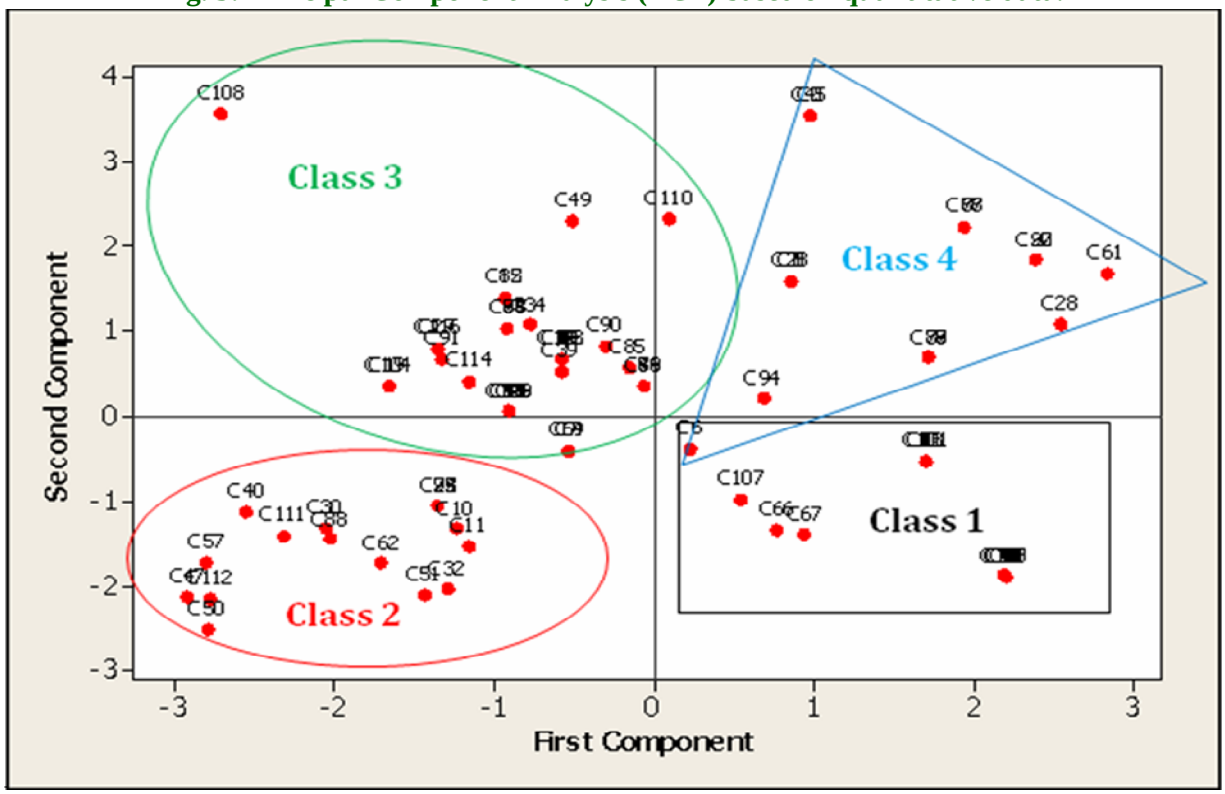


Table 8. Statistic descriptive analysis of the grouping class.

Parameters	Class 1 (15)	Class 2 (23)	Class 3 (61)	Class 4 (17)
PH	226.73±17.70a	182.91±27.02b	244.54±12.34c	194.00±41.13b
FB	109.6±8.21a	120.73±11.53a	152.13±23.5b	48.50±37.32c
NFR	6.93±0.59a	6.21±0.79a	7.7±1.72a	7.05±3.15a
DR	4.26±0.68a	4.04±0.51a	4.46±0.64a	4.30±0.65a
LR	50.97±11.12a	50.72±6.55a	45.59±9.80b	54.52±22.29c
DSt	3.22±0.96a	2.18±0.25b	3.02±1.06a	2.07±0.33b
WRF	4.72±0.91a	3.30±0.70b	3.41±1.49b	3.14±0.88b
Llo	15.8±1.88a	15.82±2.21a	16.56±3.21a	15.83±5.71a
WLo	3.53±0.47a	3.85±1.08a	4.12±0.91	4.93±3.64
Lpe	28.97±7.35a	25.47±7.78b	23.16±7.02c	23.30±7.68c
RL/l	4.50±0.56a	4.39±1.16a	4.06±0.48a	4.04±1.70a
NB: Different letters per line showed significant difference				

Conclusion

Agromorphological characterization of elite cassava cultivars collected in Benin republic revealed a significant diversity within the studied collection and highlighted the most discriminating morphological parameters. The structuring in groups of interesting and complementary agromorphological characteristics indicates possibilities for breeding and varietal improvement. Complementary studies like multi-location evaluation through different agroecological regions and molecular characterization are however necessary.

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Fig. 4: High yielding cassava elite varieties "Odohoungbo".

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