Greener Journal of Agricultural Sciences
ISSN: 2276-7770; ICV: 6.15
Vol. 6 (7), pp. 209-225, August 2016

http://gjournals.org/GJAS

GJAS

Research Article (DOI: http://doi.org/10.15580/GJAS.2016.8.062716107)

Agro-morphological Characterization of Cassava (*Manihot esculenta* Crantz) Collected in the Humid Forest and Guinea Savannah Agro-ecological Zones of Cameroon

Temegne Nono Carine[1,4]*, Mouafor Boris Igwacho[2], Ngome Ajebesone Francis[3]

[1]University of Yaoundé I, Faculty of Science, Department of Plant Biology, P.O. Box 812 Yaoundé, Cameroon.
[2]University of Yaoundé II, Faculty of Science Economics and Management, P.O Box 18 Soa, Cameroon.
[3]Institute of Agricultural Research for Development (IRAD), P.O Box 2123 Yaoundé, Cameroon.
[4]University of Bamenda, Higher Technical Teacher Training College, Department of Civil Engineering and Forestry Techniques, P.O. Box 39 Bambili, Cameroon.

Emails: 2ibmouafor @yahoo .co .uk, 3ngomajebe@ yahoo. com

ARTICLE INFO

Article No.: *062716107*
DOI: *10.15580/GJAS.2016.7.062716107*

Submitted: *27/06/2016*
Accepted: *07/07/2016*
Published: *05/08/2016*

****Corresponding Author***
Temegne Nono Carine
E-mail: *nonocarine2003 @ yahoo. fr*
Phone: *(+237)697 076 464*

Keywords:
cassava accessions, genetic diversity, agro-morphological descriptors, principal component analysis, multiple correspondence analysis

ABSTRACT

Background: Cassava (*Manihot esculenta* Crantz) is an important crop in Cameroon where leaves and tubers are eaten. However, its genetic variability remains unexplored in Cameroon. Local varieties are precious genetic resources because of their diversity. Mastery of this diversity is an important basis for crop improvement through plant breeding programs.
Methods: Local cassava accessions (89) were collected mainly in four regions belonging to the Humid Forest and Guinea Savannah agro-ecological zones. These accessions have been planted with the objective to characterize them, based on qualitative and quantitative agro-morphological traits. The experiment was carried out in experimental station of IRAD Nkolbisson, Cameroon.
Results: Significant differences ($p<0.05$) were observed for all the 14 analysed quantitative traits. Coefficients of variation of quantitative traits range from 11.85% (number of leaf lobes) to 55.75% (weight of shoot). Of the 14 quantitative traits studied, 7 had high coefficients of variation (CV>20%). The remaining 7 traits exhibit low variations. Root yields of 10 to 13 t/ha was observed with some of the accessions. The Principal Component Analysis for quantitative traits and Multiple Correspondence Analysis for qualitative traits revealed high dispersion of the accessions. On the cluster analysis for qualitative traits the accessions were classified in three groups. The dendrogram with the quantitative traits produced three main cluster groups of the cassava accessions evaluated.
Conclusion*:* This work showed the variation in agronomic traits existing among cassava accessions in the forest and savannah agro-ecological zones of Cameroon that could be exploited to enhance cassava breeding programs.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz, *Euphorbiaceae*) is the staple food of about 800 million people across the world (FAO, 2000). It is produced mainly for its roots and leaves (Ngome et al., 2013; Temegne et al., 2015a). Cassava is grown in all the five agro-ecological zones of Cameroon and is one of the most important food crops. Cassava can grow and produce acceptable yields in poor soils with low nutrient available (Temegne et al., 2015a). However, cassava production in Cameroon is still below consumption requirements. In addition, demographic projections forecast an increase in world population. This increase in population growth far exceeds that of agricultural production. The challenge for agricultural research is to contribute to increasing agricultural productivity through improved crop yields and the use of intrinsic capabilities of local accessions tolerance to diseases. To properly use these local varieties, it is imperative to identify them, to characterize them and eliminate duplicates in the collections. Lin (1991) emphasizes that the agro-morphological characterization is fundamental in order to provide information for plant breeding programs. The objective of this work was to characterize local cassava accessions collected in two agro-ecological zones of Cameroon to facilitate development of improved varieties.

MATERIALS AND METHODS

Plant material

The plant material (Table 1) was made up of 89 cassava accessions collected between January and March 2015 from the Centre, South and East Regions (Humid Forest agro-ecological zone); and in the Adamawa Region (Guinea Savannah agro-ecological zone). However a few accessions were collected from the Western and Littoral Regions.

Study site

This study was conducted at the experimental farm of IRAD Nkolbisson (N3°51'57''-3°52', E11°27'31''-11°27'36"). The Nkolbisson station is located in the humid forest agro-ecological zone with bimodal rainfall, in the Yaoundé VII Sub Division. The average daily air temperature ranges from 23-24 °C. It is characterized by rainfall from 1600 to 1800 mm per year. The site is also characterized by haplic ferralsol usually acidic. The area is governed by a Guinean equatorial climate with four seasons: a long rainy season from September to November, a long dry season from December to February, a short rainy season from March to June and a short dry season from July to August (Ngome et al., 2013).

Field trial

Cassava cuttings of 20-30 cm in length were planted at a distance of 1 m by 1m in March 2015. Each of the accessions had a total of 20 stands in two lines. Manual weeding and herbicide application were done as required. No fertilizer was applied. Harvesting was done 12 months after planting.

Data collection

Based on morphological and agronomic descriptors cassava as presented by Fukuda et al. (2010), the quantitative (Table 2) and qualitative (Table 3) parameters were recorded at three, six, nine and twelve months after planting.

Statistical analysis of the data

Data on qualitative and quantitative characters were analysed separately. For the quantitative traits the statistical analyses were performed only on root yield using the SNK (Student and Newman-keuls) tests at 5% in order to group the accessions. The average classification was performed only on a character because of the great variability among accessions. The data were processed by principal component analysis (PCA) using Minitab 16 Statistical, SPSS and SAS 9.2 (Statistical Analysis Software) softwares. PCA and correlation matrices are used to explore the links between the quantitative traits, identify and define the main characteristics of groups of accessions. Descriptive statistics (means, standard deviation, minimum, maximum, variance and coefficient of variation) and correlation coefficients analysis were computed for quantitative data. The hierarchical classification tree by UPGMA (Unweighted pair group method with arithmetic mean) automatically created groups of accessions according to the importance of the variables considered. These groups included accessions that have almost the same characteristics from the homogeneity of the elements of a class criterion (Volle, 1981). This clustering method was used for both qualitative and quantitative data. For qualitative data, descriptive statistics, multiple correspondence analysis and clustering analysis were computed.

RESULTS AND DISCUSSION

Results

Accessions No. 49 (Green petioles) and 81 (Mbam) were very seriously affected by Cassava Mosaic Virus particularly after six months of planting. These two accessions were eliminated as data collection after six months.

Table 1: List of various landraces of cassava with their code and source of collection

N°	Accessions	Villages	Regions	N°	Accessions	Villages	Regions	N°	Accessions	Villages	Regions
9	Polarouge	Belel	Adamawa	39	Campo1	Mva'a 2	Centre	69	Saa	Sa'a	Centre
10	Tokbanbwgueive	Dana	Adamawa	40	Badobo	Tikolo	East	70	Mekinda	NsongLong 2	Centre
11	Polanoircourt	Belel	Adamawa	41	Moanmoan	Nkol ossan	Centre	71	Maniocbassa1er-9	nd	Centre
12	Polanoirlong21	Belel	Adamawa	42	Mintourou	Mva'a 2	Centre	72	Ayan	Ayan	Centre
13	Gladys	Dschang	West	43	Ngambada	Soabor	Adamawa	73	Campo2	Mva'a 2	Centre
14	Mabong	Sovokong	Adamawa	44	Gbalonkpong	Gandong	East	74	Ntolbiko	Binguela 1	Centre
15	Brownstem	Yambeng	East	45	Petiolerouge	Bafia	Centre	75	Akourou1	Ovangoul	Centre
16	Manimbong	Sangmelima	South	46	Afouda	Douayel	Adamawa	76	Enouma	Obokoé	Centre
17	Polanoirlong	Belel	Adamawa	47	Ntangna	Mva'a	Centre	77	Megong	Megong	South
18	Bout	Mpemzok	East	48	Tougueda	Gbata	Adamawa	78	Ntem	Okoukouda	Centre
19	Sawada	DigouAdamou	Adamawa	49	Green petioles	Yambassa	Centre	79	Ekweme	Ekweme	South
20	Gambada	Soagol	Adamawa	50	Libogo	Adinkol	East	80	Campo18	Nkol ossan	Centre
21	Balonkpong	Dana	Adamawa	51	Petiolesrouges	Yambassa	Centre	81	Mbam1	Mbam	Centre
22	Yara	Adinkol	East	52	Tuyobo	Bethanie	East	82	Ekekam1	Ekekam	Centre
23	Maniocsucré	Soabor	Adamawa	53	Gbafdougoa	Bata	Adamawa	83	Ekekam2	Ekekam	Centre
24	Gambada1	Boumadjalé	Adamawa	54	Redpetiol	Binoum	Littoral	84	Maniocbassa	nd	Centre
25	Mabong1	Sovokong II	Adamawa	55	Fonctionnaire	Mekonkin	Adamawa	85	Owona	nd	South
26	6mois	Tikolo	East	56	Bokito	Bokito	Centre	86	Mbidaetmbani	nd	South
27	Akourakwa	Mpemzok	East	57	Gambada2	Soabor	Adamawa	87	Maniocjaune	nd	Adamawa
28	Guge	nd	Adamawa	58	Petiolevert	Bafia	Centre	88	Manmbong	Sobou 2	South
29	2e -9	nd	Adamawa	59	Greenpetiol	Binoum	Littoral	89	Nnomewondo	nd	South
30	Bitoto	Bitoto	South	60	Redpetiol	Bokito	Centre	90	Makoumba1	Ndoumalé	South
31	Nkolossan	Nkol ossan	Centre	61	Damouna	nd	Adamawa	91	Zieyabomedze	nd	Adamawa
32	Balbine	MeyosBebeng	South	62	Tymere	Koumou	South	92	Bitourou	nd	South
33	Bititi	Boumadjalé	Adamawa	63	Ntani	Koumou	South	93	Minbourou	Mindourou	East
34	Che	nd	Adamawa	64	Ntolo	Ntolo	Littoral	94	Ntangnapetiolerouge	Okoukouda	Centre
35	Madaga	nd	Adamawa	65	Yoyolo	Ovangoul I	Centre	95	Makoumba2	Mefomo	Centre
36	Mraheg	nd	Adamawa	66	Akourou	Ovangoul	Centre	96	Alotbikon	nd	Adamawa
37	Gbegueda	Gandoua	Adamawa	67	Noumpe	GarouYaka	East	97	Afobo	Nkozoa	Centre
38	Moumpe	GarouYaka	East	68	Eboa	Koumou	South				

nd: not determined

Table 2: Qualitative Characters along with their descriptors

Evaluation phase	Measured variables	Code	Scoring
3 months after planting	color of apical leaves	cal	3: light green, 5 : dark green, 7: purplish green, 9: purple
	pubescence on apical leaves	pal	0 : absent, 1 : present
6 months after planting	color of leaf vein	clv	3: green, 5: reddish-green in less than half of the lobe, 7: reddish-green in more than half of the lobe, 9: red
	petiole colour	pc	1: yellowish-green, 2 : green, 3: reddish-green, 5: greenish-red, 7: red, 9: purple
	orientation of petiole	op	1: inclined upwards, 3: horizontal, 5: inclined downwards, 7: irregular
	flowering	f	0 : absent, 1: present
	shape of central leaflet	scl	1: ovoid, 2: elliptic-lanceolate, 3: obovate-lanceolate, 4: oblong-lanceolate, 5: lanceolate, 6: straight or linear, 7: pandurate, 8: linear-piramidal, 9: linear-pandurate, 10: linear-hostatilobalate
	leaves color	lc	3 : light green, 5: dark green, 7: purple green, 9: purple
	leaf retention	lr	1 : very poor, 2 : Less than average, 3: average, 4: better than average, 5: outstanding
	lobe margins	lm	3: smooth, 5: winding
	pollen	po	0 : absent, 1: present
9 months after planting	growth habit of stem	ghs	1: straight, 2: zig-zag
	color of end branches of adult plant	ceb	3: green, 7: green- purple, 9: purple
	distance between leaf scars	dbls	3: short ≤ (8 cm), 5 : medium (8–15 cm), 7: long ≥ (15 cm)
	color of stem cortex	csco	1: orange, 2: light green, 3: dark green
	color of stem epidermis	csep	1: cream, 2: light brown, 3: dark brown, 4: orange
	color of stem exterior	csex	3: orange, 4: greeny-yellowish, 5: golden, 6: light brown, 7: silver, 8: gray, 9: dark brown
	stipule margin	sm	1: entire, 2: split or forked
	prominence of foliar scars	pfs	3: semi-prominent 5: prominent
	length of stipules	ls	3: short, 5: long
12 months after planting (harvest)	fruit	fr	0 : absent, 1: present
	seeds	s	0 : absent, 1: present
	levels of branching	lb	0: no branching
	branching habit	bh	1: erect, 2: dichotomous, 3: trichotomous, 4: tetrachotomous
	shape of plant	sp	1: compact, 2: open, 3: umbrella, 4: cylindrical
	extent of root peduncle	erp	0: sessile, 3: pedunculate, 5: mixed
	color of root cortex	crc	1: white or cream, 2: yellow, 3: pink, 4: purple
	root taste	rt	1: sweet, 2: intermediate, 3: bitter
	texture of root epidermis	tre	3: smooth, 5: intermediate, 7 rough
	color of root pulp	crp	1: white, 2: cream, 3: yellow, 4: orange, 5: pink
	external color of root	ecr	1: white or cream, 2 : yellow, 3: light brown, 4: dark brown
	root shape	rs	1: conical, 2: conical-cylindrical, 3: cylindrical, 4: irregular
	cortex thickness	ct	1: thin, 2: intermediate, 3: thick
	root constrictions	rc	1: few to none, 2: some, 3: many
	cortex: ease of peeling	cp	1: easy, 2: difficult

Table 3: Quantitative Characters along with their descriptors

Evaluation phase	Measured variables	Code	Scoring
6 months after planting	length of leaf lobe	lll	measure three leaves from the middle of the plant, measure from the intersection of all lobes to the end of the middle lobe
	width of leaf lobe	wll	measure three leaves from the middle of the plant, measure from the widest part of the middle lobe
	ratio length/width lobe	r	ratio between length and width was performed with Excel
	number of leaf lobes	nll	assess on five leaves and take the predominant number of lobes
	petiole length	pl	measure two leaves/plant from the middle third
12 months after planting (harvest)	plant height	ph	measure vertical height from the ground to the top of the canopy, record measurements from three plants
	height to first branching	hfb	measure vertical height from ground to first primary branch
	angle of branching	ab	measure at first primary branching (3), later divide by two
	number of storage roots	nsr	record from each of three plants
	number of commercial roots per plant	ncr	record the number of roots from three plants with length greater than 20 cm
	root yield	ry	measure the weight of fresh roots
	weight of shoot	ws	measure the weight of aboveground biomass
	total plant biomass	tpb	weight of roots + weight of aboveground biomass
	harvest index	hi	measure on 5 plants

Frequency distribution of accessions according to qualitative characters

Only 12% of local accessions had hair on their apical leaves. Approximately 46% of accessions had red petioles, 37% greenish-red petioles, 16% purple petioles and 1% yellowish-green petioles (Figure 1). Nearly half of the accessions (45%) had green leaf vein, 50% reddish-green (16.09% reddish-green in less than half of the lobe, 34.48% reddish-green in more than half of the lobe) and 5% red. Petioles of most accessions were horizontal (34.48%) and inclined downwards (26.44%), 24% had petioles inclined upward and 14.94% irregular petioles. Over 90% of the studied accessions had green leaves (48% light green, dark green 44%) and sweet roots (93%). Accessions with white (59) and red (27) cortex were predominant. Out of all the accessions studied, 60.92% had cylindrical, 16.09% conical-cylindrical, 12.64% conical and 10.34% irregular plant shape (Figure 1).

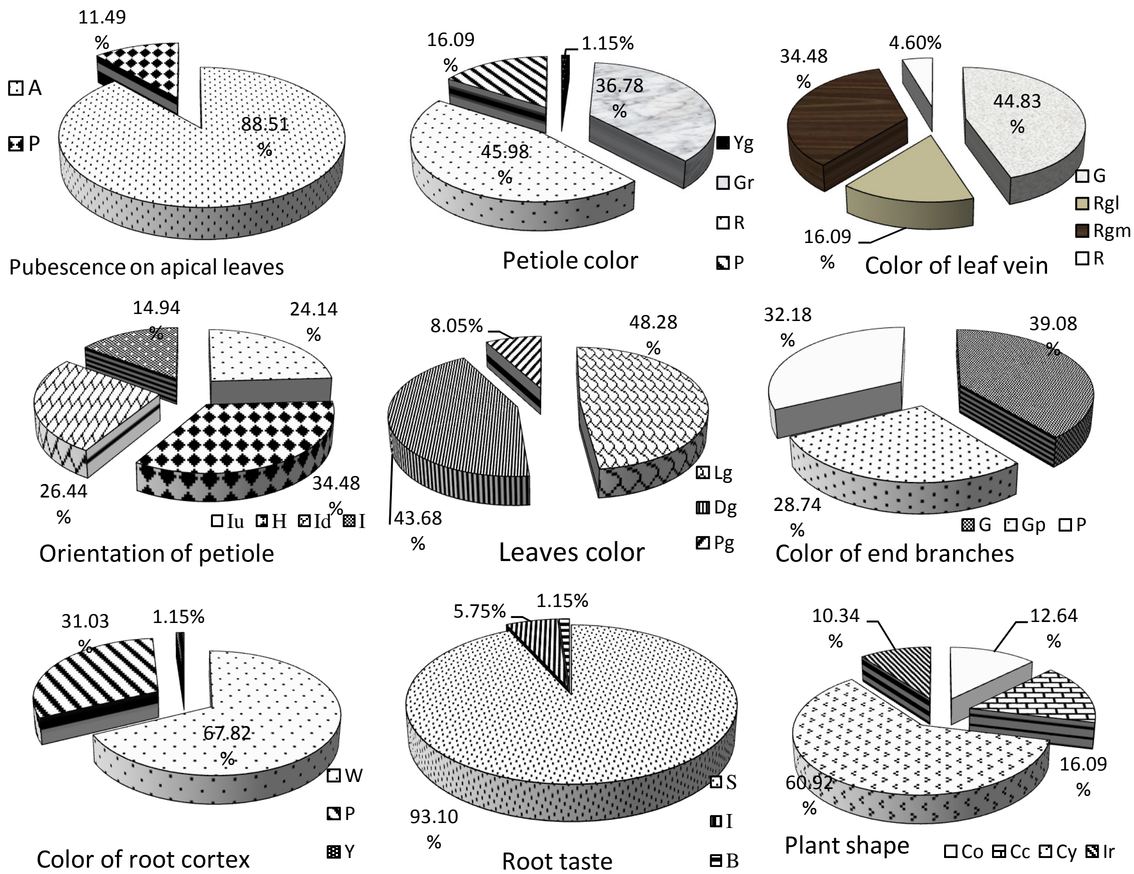

Figure 1: Frequency distribution of accessions on the basis of some qualitative agro-morphological traits. Pubescence on apical leaves (A: absent, P: present), Petiole color (Yg: yellowish-green, Gr: greenish-red, R: red, P: purple), Color of leaf vein (G: green, Rgl: reddish-green in less than half of the lobe, Rgm: reddish-green in more than half of the lobe, R: red), orientation of petiole (Iu: inclined upwards, H: horizontal, Id: inclined downwards, I: irregular), Leaves color (Lg: light green, Dg: dark green, 7: Pg: purple), Color of end branches of adult plant (G: green, Gp: green- purple, P: purple), Color of root cortex (W: white or cream, Y: yellow, P: pink), Root taste (S: sweet, I: intermediate, B: bitter), Shape of plant (Co: conical, Cc: conical-cylindrical, Cy: cylindrical, Ir: irregular).

Representation of variables of qualitative characters

Generally, the factors having eigenvalue greater than 1 are retained. The model overview table in SPSS produced on the basis of this criterion 22 factors. But only the first 10 dimensions were presented in Table 4.The objective of Multiple Correspondence Analysis (MCA) is to provide interpretable visualization of complex-variable space. The meaning given to the axes (dimensions) and analysis of proximities between variables and conditions are usually made from the factorial planes. Thus, only the first factorial plan was retained. The first two dimensions (first factorial plan) allow explaining about 32.2% of the original variance (Table 4). The strongly correlated traits (Table 5, Figure 2) to the first axis (dimension) are levels of branching (71%), branching habit (69%), shape of plant (68.8%), pollen (55.9%), flowering (55.9%) and shape of central leaflet (37.3%). The best represented characters in the dimension 2 are colour of end branches of adult plant (60.2%), petiole colour (55.3%), colour of leaf vein (54.6%), colour of root cortex (36.2%) and orientation of petiole (31.8%).

Table 4: The inertia associated with the eigenvalues of qualitative variables

Model Summary				
Dimension	Cronbach's Alpha	Variance accounted for		
		Total (Eigenvalue)	Inertia	% of Variance
1	0.849	5.578	0.186	18.593
2	0.781	4.075	0.136	13.582
3	0.727	3.369	0.112	11.230
4	0.665	2.801	0.093	9.337
5	0.630	2.560	0.085	8.533
6	0.619	2.492	0.083	8.308
7	0.605	2.406	0.080	8.022
8	0.580	2.278	0.076	7.594
9	0.555	2.155	0.072	7.184
10	0.516	1.997	0.067	6.656

Table 5: Discrimination measures of qualitative traits in dimension1-2

Discrimination Measures								
Variables	Dimension		variables (continued)	Dimension		variables (continued)	Dimension	
	1	2		1	2		1	2
fr	0.188	0.173	ceb	0.133	**0.602**	lm	0.048	0.025
s	0.188	0.173	ls	0.002	0.007	lr	0.186	0.032
lb	**0.710**	0.033	sm	0.065	0.001	lc	0.001	0.030
bh	**0.690**	0.063	ct	0.013	0.043	scl	**0.373**	0.102
sp	**0.688**	0.069	rt	0.175	0.078	f	**0.559**	0.044
pfs	0.023	0.011	tre	0.112	0.007	op	0.027	**0.318**
csco	0.020	0.182	crc	0.152	**0.362**	pc	0.047	**0.553**
csep	0.139	0.017	ecr	0.021	0.160	clv	0.094	**0.546**
csex	0.062	0.067	erp	0.033	0.123	cal	0.233	0.171
ghs	0.003	0.028	po	**0.559**	0.044	pal	0.034	0.008
Active Total							5.578	4.075
% of Variance							18.59	13.58

Codes of variables are showed in Table 2.

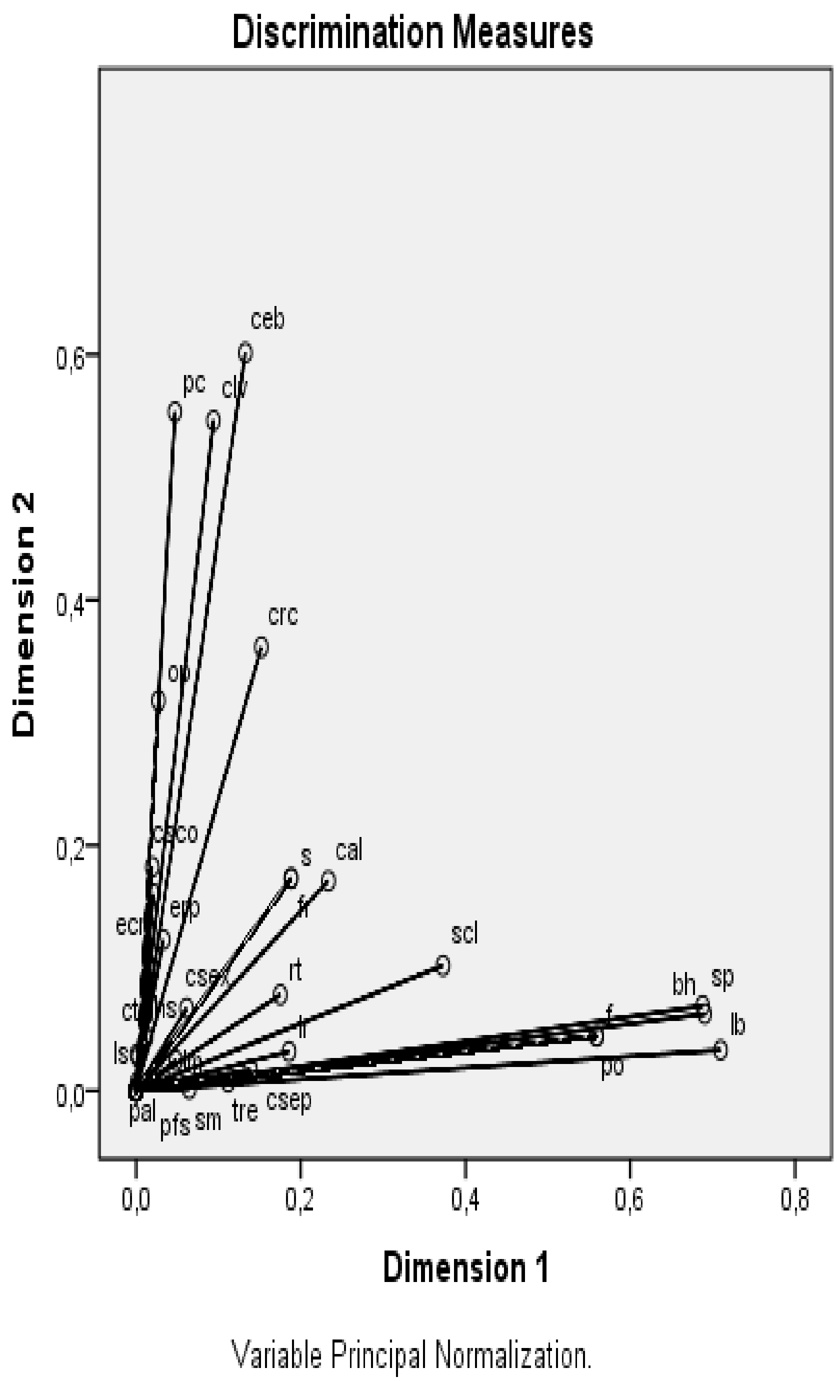

Figure 2: Representation of qualitative traits in the factor plane 1-2.
cal: color of apical leaves, pal: pubescence on apical leaves, clv: color of leaf vein, pc: petiole colour, op: orientation of petiole, f: flowering, scl: shape of central leaflet, lc: leaves color, lr: leaf retention, lm: lobe margins, po: pollen, ghs: growth habit of stem, ceb: color of end branches of adult plant, csco: color of stem cortex, csep: color of stem epidermis, csex: color of stem exterior, sm: stipule margin, pfs: prominence of foliar scars, ls: length of stipules, fr: fruit, s: seeds, lb: levels of branching, bh: branching habit, sp: shape of plant, erp: extent of root peduncle, crc: color of root cortex, rt: root taste, tre: texture of root epidermis, crp: color of root pulp, ecr: external color of root, ct: cortex thickness.

Dendogram from 35 qualitative characters

On the cluster analysis for qualitative traits, the accessions were classified in three groups (Figure 3). The first group comprises of accessions 9, 97, 10, 85, 24, 75, 48, 58, 80, 60, 50, 84, 28, 36, 88, 95, 96, 30, 64, 31, 71, 77, 57 et 87. The second group includes the accessions 13, 34, 29, 42, 14, 16, 21, 45, 73, 38, 39, 43, 93, 94, 15, 17, 35, 66, 25, 86, 27, 53, 47, 68, 41, 72, 90, 37, 51, 54, 92, 19, 22, 20, 89, 62, 67, 79 et 91. The last group brings together accessions 11, 12, 65, 61, 33, 59, 18, 44, 23, 76, 56, 26, 40, 55, 78, 32, 46, 52, 74, 63, 69, 70, 82 et 83.

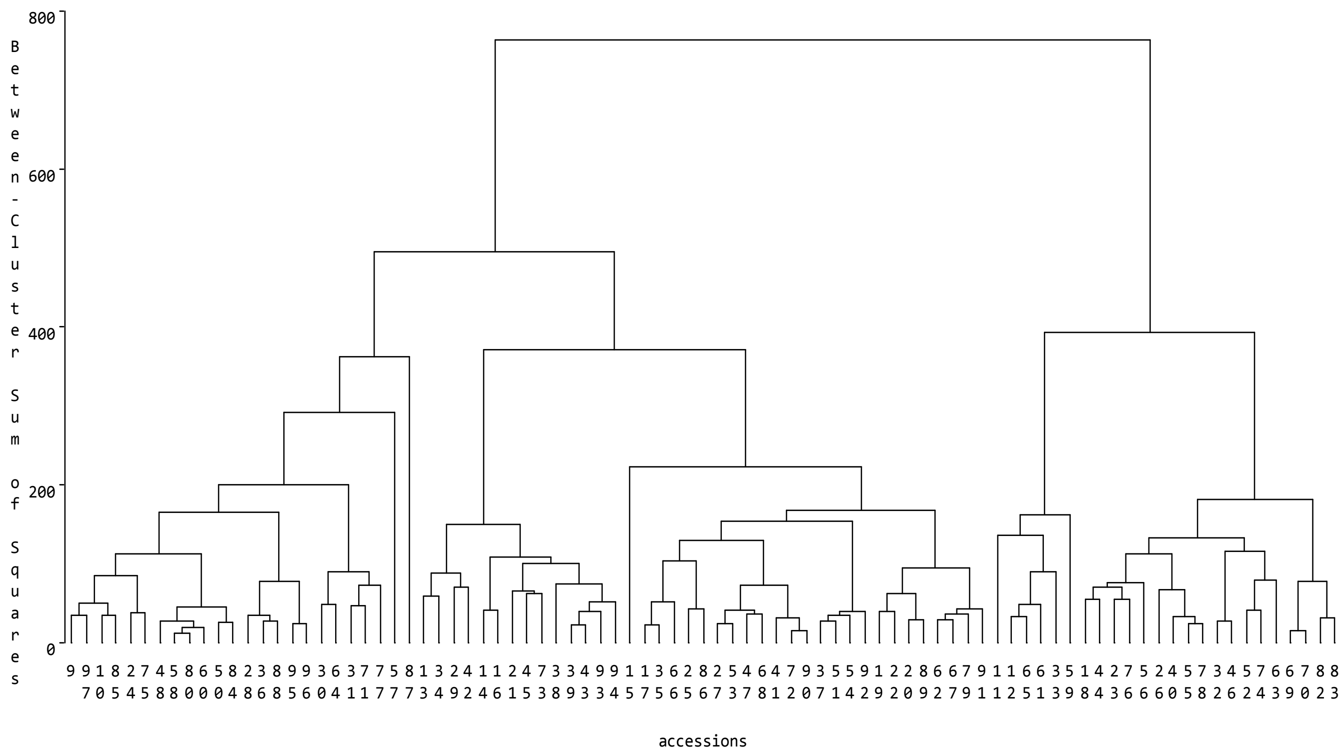

Figure 3: Dendrogram of accessionsderived by UPGMA from qualitative traits. Codes of cultivars are showed in Table 1

Descriptive statistics of quantitative traits

The cassava accessions revealed variability for the fourteen evaluated quantitative morphological characters (Table 6). The range of values produced were 1.7 to 4.1 m for plant height, 2 to 22 for the number of fresh storage roots per plant, 2 to 18 for the number of fresh commercial roots per plant, 14 to 30.3 cm for the length of leaf lobe, 4 to 8.5 for width of leaf lobe, 2.1 to 6.5 for the ratio length/width lobe, 5 to 9 for number of leaf lobes, 14.5 to 36 for petiole length, 1.5 to 17.5 kg for the fresh root weight, 0.5 to 17 kg for weight of shoot, 2.3 to 34.5 kg for total plant biomass and 0.06 to 0.8 for harvest index (Table 6). Coefficients of variation range from 11.85% (number of leaf lobes) to 55.75% (weight of shoot). Of the 14 quantitative traits studied, 7 had high coefficients of variation (CV> 20%). Seven (7) others exhibit low variations. The variability among the cassava accessions for all quantitative characters was demonstrated by significant differences (P<0.05) (Table 6).

Table 6: Descriptive statistics and ANOVA of quantitative characters

Variables	Means	SD	Min	Max	V	CV	p
Plant height (ph)	2.87	0.54	1.70	4.10	0.30	19.01	0.000***
Height to first branching (hfb)	1.39	0.61	0.00	3.56	0.38	44.55	0.000***
Angle of branching (ab)	48.48	16.68	0.00	67.50	278.11	34.40	0.000***
Length of leaf lobe (lll)	23.15	3.26	14.00	30.30	10.64	14.09	0.000***
Width of leaf lobe (wll)	6.33	0.92	4.00	8.50	0.86	14.63	0.000***
Ratio length/width lobe (r)	3.72	0.65	2.10	6.50	0.43	17.65	0.000***
Number of leaf lobes (nll)	7.35	0.87	5.00	9.00	0.76	11.85	0.001**
Petiole length (pl)	25.59	4.51	14.50	36.00	20.42	17.66	0.000***
Number of storage roots (nsr)	7.61	3.14	2.00	22.00	9.86	41.27	0.000***
Number of commercial roots (ncr)	9.39	3.81	2.00	18.00	14.54	40.62	0.000***
Root yield (ry)	5.05	2.29	1.50	17.50	5.28	45.55	0.000***
Weight of shoot (ws)	4.47	2.48	0.50	17.00	6.20	55.75	0.000***
Total plant biomass (tpb)	9.49	4.42	2.30	34.50	19.59	46.65	0.000***
Harvest index (hi)	0.54	0.09	0.06	0.80	0.01	17.89	0.000***

*SD: standard deviation, V: variance, CV: coefficient of variation, **: Significant at a 0.01 probability level, ***: significant at a 0.001 probability level.*

Correlation matrix of quantitative traits

The correlation table shows that plant height was significantly and positively correlated to all the quantitative traits, except harvest index where it is significantly and negatively correlated (Table 7). Height to first branching is very highly significantly ($p<0.001$), r^2: 0.618) correlated with angle of branching and width of leaf lobe ($p<0.01$, r^2: 0.186). A very highly significant difference ($p<0.001$) was observed between width and length of leaf lobe and ratio length/width lobe (Table 5). Length of leaf lobe is very highly significantly ($p<0.001$) correlated to width of leaf lobe (r^2: 0.272), ratio length/width lobe (r^2: 0.524), petiole length (r^2: 0.316), number of storage roots per plant (r^2: 0.311), number of commercial roots per plant (r^2: 0.316), root yield (r^2: 0.250), weight of shoot (r^2: 0.278), total plant biomass (r^2: 0.279) and very significantly ($p <0.01$) and negatively correlated with the harvest index (r^2: -0175).The root yield (Table 5) is very highly ($p<0.001$) correlated to number of storage roots (r^2: 0.619), number of commercial roots per plant (r^2: 0.664), weight of shoot (r^2:0.729), total plant biomass (r^2: 0.925), petiole length (r^2: 0.293) and length of leaf lobe (r^2: 0.250).

Table 7: Pearson correlation matrix of 14 quantitative characters

	ph	hfb	Ab	lll	wll	r	nll	pl	nsr	ncr	ry	hi	ws	tpb
ph	1													
hfb	0,144 *	1												
ab	-0,255 ***	0,618 ***	1											
lll	0,409 ***	0,085 ns	-0,030 Ns	1										
wll	0,190 **	0,186 **	0,150 *	0,272 ***	1									
r	0,178 **	-0,068 ns	-0,169 **	0,524 ***	-0,518 ***	1								
nll	0,184 **	0,041 ns	-0,053 Ns	0,068 ns	0,192 **	-0,056 ns	1							
pl	0,372 ***	0,045 ns	-0,171 **	0,316 ***	0,183 **	0,103 ns	0,359 ***	1						
nsr	0,210 **	0,094 ns	0,004 Ns	0,311 ***	0,136 *	0,130 *	0,048 ns	0,263 ***	1					
ncr	0,186 **	0,051 ns	0,020 Ns	0,316 ***	0,160 *	0,076 ns	0,047 ns	0,270 ***	0,864 ***	1				
ry	0,151 *	-0,095 ns	-0,031 Ns	0,250 ***	0,107 ns	0,026 ns	0,011 ns	0,293 ***	0,619 ***	0,664 ***	1			
hi	-0,240 ***	-0,112 ns	-0,175 **	-0,175 **	-0,071 ns	-0,107 ns	-0,146 *	-0,061 ns	-0,079 ns	-0,033 ns	0,058 ns	1		
ws	0.254 ***	0.018 ns	0.122 *	0.278 ***	0.113 ns	0.079 ns	0.092 ns	0.252 ***	0.526 ***	0.535 ***	0.729 ***	-0.578 ***	1	
tpb	0.221 ***	-0.035 ns	0.050 ns	0.279 ***	0.110 ns	0.060 ns	0.060 ns	0.290 ***	0.618 ***	0.645 ***	0.925 ***	-0.268 ***	0.928 ***	1

**: p<0.05 (significant difference), **: p<0.01 (highly significant difference), ***: p<0.001 (very high significant difference), ns: non-significant. lll:length of leaf lobe, wll: width of leaf lobe, r: ratio length/width lobe, nll: number of leaf lobes, pl: petiole length, ph: plant height, hfb: height to first branching, ab: angle of branching, nsr: number of storage roots, ncr: number of commercial roots per plant, ry: root yield, ws: weight of shoot; tpb: total plant biomass, hi: harvest index*

Representation of variables of quantitative traits

According to the Kaiser criterion, dimensions (axes) with its own value greater than 1 must be kept for proper representation of variables. These dimensions are provided by the PCA. According to the criterion of the elbow, on the scree of values, there is a breakage (elbow or knee flexion) followed by a steady decline. Then the axes are selected before the breakage. According to these two criteria, the first five axes are preserved. Their values are respectively 4.394, 1.921, 1.742, 1.497 and 1.217 (Table 8). The first five principal components best explains the diversity of cassava accessions. The five main components represent 76.90% share of information. The first factorial plane (1-2) contains 31.40% of the original variance data (Table 8, Figure 4). The variables significantly correlated with axe 1 are: total plant biomass (90.5%), shoot weight (85.4%), root yield (83.1%), number of commercial roots (80.1%), number of storage roots (79%), length of leaf lobe (51.5%) and petiole length (47.4%). The variables significantly correlated to the axe 2 are: angle of branching (78.6%), height to first branching (66.8%), ratio length/width lobe (-63.5%) and width of leaf lobe (54.4%). The variables significantly related to axe 3 are: plant height (60.9%), length of leaf lobe (48.8%), number of leaf lobes (48.5%) and petiole length (44.5%). The variables significantly correlated to the axe 4 are: ratio length/width lobe (-62%) and width of leaf lobe (51%). The variables significantly correlated to the axe 5 are: harvest index (66%) (Table 8, Figure 4).

Table 8: Coefficient and vector association with the first 5 principal components (PC)

Characteristics	Principal components (PC)				
	PC1	PC2	PC3	PC4	PC5
Eigenvalue	4.394	1.921	1.742	1.497	1.217
Proportion (%)	31.385	13.721	12.445	10.693	8.695
Cumulative (%)	31.385	45.107	57.551	68.244	76.939
Coefficient vector					
Plant height (ph)	0.423	-0.169	**0.609**	0.071	0.008
Height to first branching (hfb)	0.067	**0.668**	0.301	-0.340	0.371
Angle of branching (ab)	0.009	**0.786**	-0.060	-0.438	0.139
Length of leaf lobe (lll)	**0.515**	-0.207	**0.488**	-0.222	0.334
Width of leaf lobe (wll)	0.238	**0.544**	0.295	**0.510**	0.101
Ratio length/width lobe (r)	0.175	**-0.635**	0.235	**-0.620**	0.195
Number of leaf lobes (nll)	0.172	0.079	**0.485**	0.372	-0.245
Petiole length (pl)	**0.474**	-0.141	**0.445**	0.333	0.070
Number of storage roots (nsr)	**0.790**	0.002	-0.200	0.021	0.299
Number of commercial roots (ncr)	**0.801**	0.014	-0.244	0.077	0.301
Root yield (ry)	**0.831**	-0.054	-0.395	0.139	0.029
Weight of shoot (ws)	**0.854**	0.118	-0.123	-0.187	-0.421.
Total plant biomass (tpb)	**0.905**	0.033	-0.280	-0.027	-0.204
Harvest index (hi)	-0.314	-0.205	-0.339	0.425	**0.660**

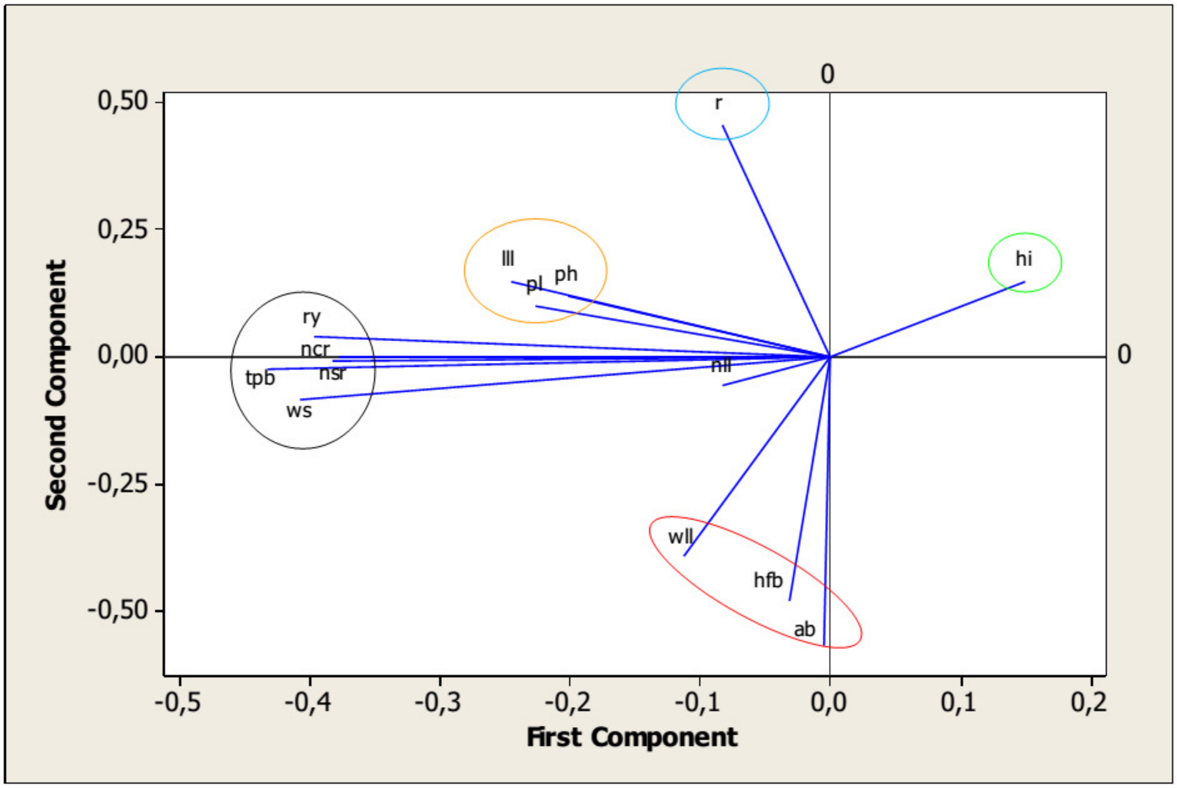

Figure 4: Representation of quantitative variables in the factor plane 1-2. lll: length of leaf lobe, wll: width of leaf lobe, r: ratio length/width lobe, nll: number of leaf lobes, pl: petiole length, ph: plant height, hfb: height to first branching, ab: angle of branching, nsr: number of storage roots, ncr: number of commercial roots per plant, ry: root yield, ws: weight of shoot; tpb: total plant biomass, hi: harvest index.

Dendogram from 14 quantitative traits

Hierarchical classification grouped accessions into three classes almost with the same characteristics as a function of the variables (Figure 5, Table 9). Group 1 consisted mainly of accessions with low yields. The group 2 essentially comprised of middle-yield accessions. The group 3 is mostly composed of high-yield accessions.

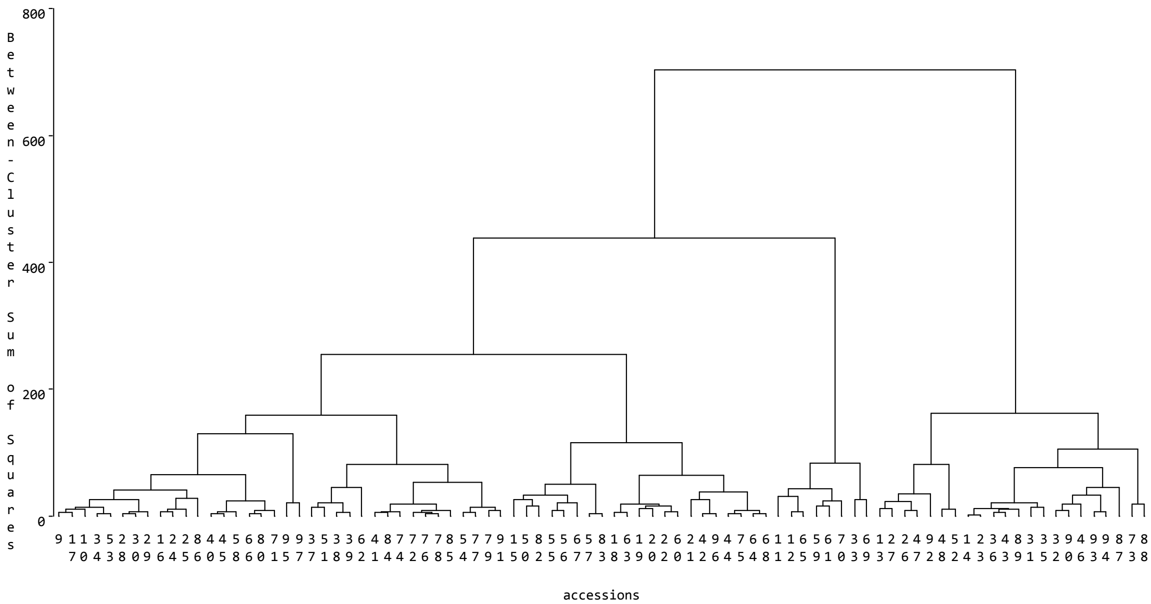

Figure 5: Dendrogram of accessions derived by UPGMA Person correlation coefficient from 14 quantitative traits. Codes of cultivars are showed in Table 1

Table 9: Distribution of cassava accessions in different clusters

Cluster	Accessions
1	9, 17, 10, 34, 53, 28, 30, 29, 16, 24, 25, 86, 40, 45, 58, 66, 80, 71, 95, 97, 37, 51, 38, 39, 62, 41, 84, 74, 72, 76, 78, 85, 54, 77, 79, 91, 15, 50, 82, 55, 56, 67, 57, 83, 18, 63, 19, 20, 22, 60, 21, 42, 96, 44, 75, 64, 68,
2	11, 12, 65, 59, 61, 70, 33, 69
3	13, 27, 26, 47, 92, 48, 52, 14, 23, 36, 43, 89, 31, 35, 32, 90, 46, 93, 94, 87, 73, 88

Codes of cultivars are showed in Table 1.

Accessions classification according to root yield

Mean structuring tests of Student and Newman-Keuls were used to classify the average of character roots yield (Table 10). According to this classification, seven local accessions (No. 52, 48, 47, 27, 69, 26 and 86) can be selected for the varietal improvement program.

Table 10: Anova test to classified accessions by root yield

N° acc	Yield *10^4 (kg.ha^{-1})	N° acc	Yield*10^4(kg.ha^{-1})	N° acc	Yield *10^4 (kg.ha^{-1})
9	5.33±0.57 cdefghi	38	4.17±0.76 cdefghi	68	2.07±0.11 hi
10	6.17±1.25 cdefghi	39	4.33±1.44 cdefghi	**69**	**8.40±0.69 bcde**
11	5.83±1.25 cdefghi	40	4.17±0.76 cdefghi	70	5.33±1.04 cdefghi
12	4.50±0.86 cdefghi	41	2.50±0.86 ghi	71	6.67±2.08 cdefgh
13	7.50±0.50 cdefg	42	4.00±1.00 defghi	72	5.17±2.36 cdefghi
14	6.83±1.04 cdefgh	43	6.67±3.75 cdefgh	73	7.50±0.86 cdefg
15	3.97±0.45 defghi	44	3.07±0.90 fghi	74	2.90±1.38 fghi
16	6.83±0.28 cdefgh	45	4.17±2.08 cdefghi	75	3.67±1.15 defghi
17	4.67±0.28 cdefghi	46	6.33±0.57 cdefghi	76	3.73±2.05 defghi
18	4.00±1.32 defghi	**47**	**9.00±0.00 bc**	77	5.00±1.73 cdefghi
19	4.50±0.50 cdefghi	**48**	**11.33±4.51 ab**	78	4.00±0.00 defghi
20	4.60±0.36 cdefghi	50	3.23±0.25 fghi	79	5.17±0.28 cdefghi
21	2.87±1.00 ghi	51	2.42±0.52 ghi	80	5.50±0.86 cdefghi
22	5.40±0.52 cdefghi	**52**	**12.67±4.19 a**	82	4.50±2.78 cdefghi
23	6.07±0.40 cdefghi	53	5.17±0.57 cdefghi	83	2.33±0.57 hi
24	6.17±2.02 cdefghi	54	3.83±0.28 defghi	84	2.33±0.28 hi
25	6.67±2.25 cdefgh	55	4.50±0.50 cdefghi	85	3.33±0.57 efghi
26	**8.00±1.00 bcdef**	56	3.67±1.15 defghi	**86**	**8.00±2.00 bcdef**
27	**8.67±0.57 bcd**	57	1.50±0.00 i	87	5.17±3.18 cdefghi
28	6.23±0.75 cdefghi	58	4.73±1.55 cdefghi	88	3.83±2.75 defghi
29	6.40±1.44 cdefghi	59	4.50±2.78 cdefghi	89	7.00±2.29 cdefgh
30	7.50±1.80 cdefg	60	4.33±0.57 cdefghi	90	3.83±1.44 defghi
31	7.00±2.29 cdefgh	61	4.50±0.50 cdefghi	91	4.83±0.28 cdefghi
32	5.17±1.15 cdefghi	62	2.07±0.11 hi	92	5.67±0.57 cdefghi
33	7.17±1.76 cdefgh	63	2.33±0.28 hi	93	3.50±1.50 efghi
34	5.50±0.50 cdefghi	64	3.00±0.50 fghi	94	5.33±1.52 cdefghi
35	5.33±0.57 cdefghi	65	4.00±0.86 defghi	95	4.17±0.76 cdefghi
36	5.83±1.52 cdefghi	66	4.50±0.86 cdefghi	96	3.67±0.57 defghi
37	3.67±1.52 defghi	67	3.67±1.60 defghi	97	3.67±0.76 defghi

Codes of cultivars are showed in Table 1. Values followed by the same letters are not significantly different at the 5%. Acc: Accessions

DISCUSSION

About 12% of local accessions had hair on their apical leaves. Indeed, few wild cassava accessions are pubescent; this trait is most often encountered in improved accessions and contributes to their tolerance to pests and diseases. For example, resistant varieties have hair on their base, which prevents harmful insects such as mites.

The first axis of representation of qualitative characters is related to the architecture of the plant while the second axis comprises the distinctive coloration traits. Dendrogram of accessions derived by UPGMA from qualitative traits have given three groups. The variation in traits observed (phenotype) does not only reflect the genetic constitution of the accession. But it also reflects the interaction of the genotype with the environment (genotype × environment) within which it is expressed (Noerwijati et al., 2013). Phenotypic variance in cassava is higher than genotypic variance for traits of agronomic importance like root yield. The qualitative characteristics are considered as the most important traits to identify a particular plant accession. Qualitative traits are usually genetically controlled. They are therefore less independent to the response of the environment.

Coefficients of variation range from 11.85% (number of leaf lobes) to 55.75% (weight of shoot). This result is similar to those of Agre et al. (2016) which found that the number of leaf lobes has the lowest coefficient of variation. Of the 14 quantitative traits studied, 7 had high coefficients of variation. The high coefficients of variation observed for the examined characters indicated the presence of a high heterogeneity within the population characterized that can be exploited for breeding. Shoot weight presents the highest coefficient of variation; it is an important character in the recommendation for planting of cassava accessions. This trait shows the potential to produce stem cuttings and the possibility of using parts of the shoots as protein source in animal feed (Ceballos et al., 2004). There is variability among the cassava accessions for all quantitative characters. According to Vieira et al. (2011), this variability could be explained by the presence of improved and unimproved accessions of different origins. Indeed, the characteristics of some local accessions were similar to those of improved varieties produced by IRAD. The farmers could have domesticated and renamed these improved varieties. The difference between these cassava accessions could also be explained by the existence of genotypic difference (Temegne et al., 2015a).

Plant height was significantly correlated to all the quantitative traits. Indeed, Agre et al. (2015) showed that plant height is the principal character that is significantly and positively correlated with the height to first plant branching, the number of roots per plant, the fresh root yield and the number of leaf lobes. The correlation data constitutes an important tool in the selection of characters to include in cassava breeding programs.

The first two components explain 31.40% of the total cumulative variance. This result is similar of those of Afonso et al. (2014) who found 32.56% to the first factorial plane. This is justified by the fact that it was included many main component. It can also be explained by the fact that the variance distribution is associated with the nature and number of characters used in the analysis and focuses on the first principal components. For interpretation of factorial axes of quantitative characters, it is observed that the first axe is related to cassava production (yield). The second axe is the axe of the plant habit (plant shape). The third axe is an axe which refers to the dimensions of the plant. The fourth and fifth axes are relative to the distribution of biomass. It follows from the above analysis that the five (5) axes have a fairly precise meaning and refer to specific traits.

Seven local accessions (No. 52, 48, 47, 27, 69, 26 and 86) can be selected for the varietal improvement program according to root yield. Indeed, despite the attacks of pests (mites, mealybugs, African cochineal of roots and tubers) and diseases (mosaic virus cassava, anthracnose, and cassava bacterial blight), these accessions were able to maintain a biomass and a high yield. These accessions may possess the genes that confer tolerance to pests and diseases. The seven best accessions have yields of from 9 to 13 t/ha. Indeed, the works of IRAD (2008) and Temegne et al. (2015a) show that local cassava varieties have a yield potential ranging between 10-12 t/ha. The work of Agre et al. (2015) in Benin has shown that the best local accession had a yield of $5.8*10^4$ kg/ha (weight of fresh root: 5.8 kg). So the best local cassava accession of Cameroon has a yield ($17.5*10^4$ kg/ha) three times higher than the highest accession of Benin. Although Cameroonian soils as soils of sub-Saharan African countries is deficient in nutrients (FAO, 2003; Ngome et al., 2013; Temegne et al., 2015b), its nutrient composition is greater compared to the soils of Benin (Mbogne et al., 2015). The majority of low-yielding accessions in roots showed a growth of the aerial part (weight of shoot) more important than that of the underground part (ry). Nutrient translocation would in this case preferentially to the stems at the expense of tuberous roots. The low yield of some accessions can also be explained by their susceptibility to disease and pests. These perturb physiology and reduce normal plant growth.

CONCLUSION

The aim of this study was to perform agro-morphological characterization of local cassava accessions collected in two agro-ecological zones of Cameroon. The great variability among accessions and ranking them in groups based on agro-morphological characteristics showed that there are opportunities for plant breeding. However, this work should be completed by characterizing cassava accessions in other agro-ecological zones of Cameroon. Molecular characterization of the cassava accessions is also imperative to further refine the characteristics of these accessions and eliminate repeats in the germplasm collection of IRAD.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

The author Temegne Nono Carine collected the data and drafted the manuscript. The author Mouafor Boris Igwacho read and corrected the draft of the manuscript. The author Ngome Ajebesone Francis elaborated the data collection protocol, facilitated fieldwork and corrected the draft of the manuscript.

ACKNOWLEDGEMENTS

The authors appreciate the financial support obtained from C2D PAR project and the Ministry of Scientific Research and Innovation (MINRESI) Cameroon, and also acknowledge the logistical support from IRAD Nkolbisson.

REFERENCES

Agre AP, Dansi A, Rabbi IY, Battachargee R, Dansi M, Melaku G, Augusto B, Sanni A, Akouegninou A and Akpagana K (2015). Agromorphological characterization of elite cassava (*Manihot esculenta* Crantz) cultivars collected in Benin. Int. J. Curr. Res. Biosci. Plant Biol. 2(2): 1-14.www.ijcrbp.com.

Afonso SDJ, Ledo CAdaS, Moreira RFC, Silva SdeOe, Leal VDdeJ and Conceição ALdaS (2014). Selection of descriptors in a morphological characteristic considered in cassava accessions by means of multivariate techniques. IOSR-JAVS. 7(1): 13-20. www. iosrjournals.org.

Ceballos H, Iglesias CA, Pérez JC and Dixon AGO (2004). Cassava breeding: opportunities and challenges. Plant Molecular Biology 56: 503-516.

FAO (Food and Agriculture Organization) (2000). Défendre la cause du manioc. FAO: Rome. http://www.fao.org/nouvelle/2000/000405-f.htm.

FAO (Food and Agriculture Organization) (2003). Gestion de la fertilité des sols pour la sécurité alimentaire en Afrique subsaharienne. FAO: Rome.

Fukuda WMG, Guevara CL, Kawuki R and Ferguson ME (2010). Selected morphological and agronomic descriptors for the characterization of cassava. International Institute of Tropical Agriculture (IITA): Ibadan (Nigeria).

IRAD (2008). Rapport national sur l'état des ressources phytogénétiques pour l'alimentation et l'agriculture. IRAD: Yaoundé (Cameroun).

Lin MS (1991). Genetic base of japonica rice varieties released in Taiwan. Euphytica 56: 43-46.

Mbogne JT, Temegne CN, Hougnandan P, Youmbi E, Tonfack LB and Ntsomboh-Ntsefong G (2015). Biodiversity of arbuscular mycorrhizal fungi of pumpkins (*Cucurbita* spp.) under the influence of fertilizers in ferralitic soils of Cameroon and Benin. J. App. Biol. Biotech. 5(3):1-10. DOI:10.7324/jabb.2015.3501.

Ngome AF, Amougou MFC, Tata PI, Ndindeng SA, Mfopou MYC, Mapiemfu-Lamare D and Njeudeng TS (2013). Effects of cassava cultivation on soil quality indicators in the humid forest of Cameroon. Greener J. Agric. Sci. 3: 451-457. www.gjournals.org.

Noerwijati K, Nasrullah T and Djoko P (2013). Breeding value estimation of fifteen related cassava genotypes using blup. J. Agricult. Biol. Sci. 8(4): 317-321.

Temegne NC, Ngome AF and Fotso KA (2015a). Influence de la composition chimique du sol sur la teneur en éléments nutritifs et le rendement du manioc (*Manihot esculenta* Crantz, *Euphorbiaceae*) dans deux zones agro-écologiques du Cameroun. Int. J. Biol. Chem. Sci. 9(6): 2776-2788. DOI : http://dx.doi.org/10.4314/ijbcs.v9i6.21.

Temegne NC, Mbogne TJ, Nbendah P, Youmbi E, Taffouo VD and Ntsomboh-Ntsefong G (2015b). Effect of phosphate deficiency on growth and phosphorus content of three Voandzou (*Vigna subterranean* (L.) Verdc.) varieties. IOSR JAVS. 8(9): 52-59. DOI: 10.9790/2380-08915259.

Vieira EA, Fialho J de F, Faleiro FG, Bellon G, da Fonseca KG, Carvalho LJCB, Silva MS, de Paula-Moraes SV, de Oliveira CM and Denke ML (2011). Characterization of sweet cassava accessions based on molecular, quantitative and qualitative data. Crop Breed. Appl. Biotechnol. 11(3). http://dx.doi.org/10.1590/S1984-70332011000300005.

Volle M (1981). Analyse des données. Economica: Paris.

Cite this Article: Temegne NC, Mouafor BI, Ngome AF (2016). Agro-morphological Characterization of Cassava (*Manihot esculenta* Crantz) Collected in the Humid Forest and Guinea Savannah Agro-ecological Zones of Cameroon. Greener Journal of Agricultural Sciences, 6(7): 209-225, http://doi.org/10.15580/GJAS.2016.8.062716107.