IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
June 2018 Vol.:9, Issue:4

Screening of Local Cassava (*Manihot esculenta* Crantz) Varieties for Resistance to Cassava Mosaic Virus in the Bimodal Rainfall Zone of Cameroon

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Submission: 19 May 2018
Accepted: 25 May 2018
Published: 30 June 2018

HUMAN JOURNALS
www.ijsrm.humanjournals.com

Keywords: *Manihot esculenta*, local varieties, mosaic virus, screening, tolerance, food security.

ABSTRACT

A study was carried out in Cameroun to assess the resistance of 86 local and six improved cassava varieties to viral mosaic disease. Cuttings of each variety were collected from different localities of the Center Region and grown at the experimental station of the Institute of Agricultural Research for Development in Yaounde. The disease was assessed in the field by visual observations of the viral symptoms while incidence and severity were also assessed. Similarly, morphological parameters were evaluated six (6) months after planting. The results obtained from the morphological studies showed that the leaf color was dark green, average number of branches on the majority of the varieties was 3, the average length of the lobes was 16.46 cm, the average length of the petiole was 22 cm, and the mean lobe number was 5. Screening analysis, on the other hand, showed that the mosaic virus infected most of the varieties with significant effects observed in local varieties when compared to the improved varieties which showed resistance to mosaic, example 8034, 92/0326, *Excel*, and *Champion*. Using both the Principal Component Analysis (PCA) and cluster analysis (dendrogram), we identified a mismatch tolerance in about thirty local varieties that showed low severity including3.83 ± 0.62, 12.00 ± 8.18, 19.66 ± 11.50, 20.00 ± 11.00 and20.66 ± 1.00 % respectively on varieties *Nkol-Ossane/18*, *Red Petiole Bafia*, *Afobo Nkozoa*, *Makumba II* and *Mbida-Mbani*. Based on our results, we recommend the introduction of mosaic-tolerant local varieties to farmers as viable alternative control method against Cassava mosaic virus. Such a control method will equally improve the production of cassava in many localities of bimodal rainfall zone of Cameroon, thus solving the problems of food insecurity.

INTRODUCTION

Cassava is a plant with starchy roots, rustic, simple, adapted to diverse cropping and environmental conditions. It is ranked as the world's fifth most important food product and has become an important source of raw materials for industry and a contributor to food security (Ambang *et al.*, 2007). Cassava is the second most important food crop in Cameroon after maize. It is one of the main products consumed in different forms by different localities in Cameroon. Cassava is cultivated in all the five agro-ecological zones of the country and is considered as the basic staple of more than 800 million people in tropical Africa. World production of cassava is estimated at about 268.28 Mt. In Cameroon, the national production of cassava is 4.92 Mt (Anonymous, 2016). This relatively low production potential of cassava in Cameroon is reportedly linked to the advent of pests and diseases in general, and CMV in particular (Maho, 2017, Ambang *et al*., 2009). The disease has become a persistent and significant threat to the production of cassava in Cameroon, causing significant yield losses per hectare. The mosaic that results from CMV infection causes a metabolism disorder that leads to decreased carbon and nitrogen content in diseased leaves (Beck and Chant, 1958) and increased transpiration, respiration and peroxidase activity (Chant *et al*., 1971). Cassava mosaic virus is responsible for the reduction of chlorophyll a and b (Ayanru and Sharma, 1982). Given the nutritional and economic importance of cassava; considering the ecological, human and demographic potential, it is imperative to optimize the yield while preserving the environment. Integrated pest management methods are viable alternatives to the lack of adequate curative measures against the virus and necessitate controlling the ecology of the virus while improving the genetic potential of plant material via resistance to disease and other pests. In Cameroon, several studies on pathogens that infect cassava have focused on fungi diseases with little or no attention to viruses. Information is therefore scanty and relatively undocumented on both the incidence, prevalence and impact of viruses on the yield of cassava, as well as the availability of resistant varieties for poor resource formers (Ambang *et al*., 2016, Maho, 2017). Here, we report the results of screening 86 local varieties of cassava for resistance to cassava mosaic virus. The resistant varieties identified will be included in the National Catalog of Cassava Varieties and used in integrated disease management strategies to increase the production of cassava, hence reduce food insecurity.

MATERIALS AND METHODS

1. Plant Material

The plant material was made up of symptomatic and asymptomatic local and improved varieties, cultivated in monoculture. The local varieties were obtained from the farms of peasant cassava producers in several localities of the bimodal rainfall zone of the Center Region of Cameroon, while improved varieties came from the Institute of Agricultural Research for Development, Cameroon.

2. Other materials

Other materials used to carry out this work included; a graduated scale for length measurement, a Samsung digital camera, data collection sheets and a Cours Grade Scale (1951) used to determine the severity of symptoms.

3. Methods

3.1. Characterization of cassava varieties in the study site

The characterization of cassava varieties was done through visual identification of the varieties by assigning it a name and/or code corresponding either to the locality of origin and, or according to the morphological characteristics recorded in the field (Leaf color, petiole color, lobe length, leaf shape, number of lobes, number of branches). The cassava varieties collection sheet proposed by Manusset (2006) was used for the purpose.

3.2. Epidemiology of cassava mosaic virus

The epidemiology of cassava mosaic disease in the field was determined by evaluating disease incidence and severity based on the visual diagnosis of the symptoms. To do this, we used an on-line device for local accessions (at a rate of 30 plants per line and per variety) and one block for the improved varieties. The 5-squared method (Zinga *et al*., 2008) was applied. It consists of delimiting in each block, four squares of 15 m^2 each of the 4 angles and 1 square in the center of each block. Thirty (30) plants per square were used and a general mean was determined per variety.

For the evaluation of symptoms observed on the leaves, the scale of intensity of disease was used to assign indices to the plants showing symptoms of the disease at different stages as

follows: (0): no symptoms; (1): slight mosaic without deformation or size reduction covering less than 1/3 of the leaf surface; (2): mosaic with no net reduction in size and covering less than half of the leaf area with occasional deformation of the leaf; (3): mosaic covering the major part of the leaf, accompanied by deformations and a reduction of the surface; (4): mosaic covering the entire surface, accompanied by severe deformation and dwarfism of the leaf; (5): Applied when the leaflets are practically reduced to the ribs.

3.2.1 Incidence of cassava mosaic virus disease

Disease incidence was assessed as the frequency of occurrence of disease on the plants in lines or blocks and was determined using the formula of Tchoumakov and Zaharova (1990):

$$P = (n / N) \times 100, \text{ where;}$$

P = incidence or frequency (%) of disease in plot;

N =number of diseased plants in the plot;

N= total number of plants in the plot.

3.2. Determination of mosaic severity

Disease severity was determined on symptomatic leaves and the results converted to the percentage for each plant. To obtain specific values for disease severity, we used the formula proposed by Tchoumakov and Zaharova (1990) which is expressed as follows: $S = \Sigma (a.b) / N$

Where $\Sigma (a.b)$: the sum of the multiplications of the number of diseased plants (a) by the corresponding degree of infection (b) given as a percentage; N: the total number of diseased plants.

3.3. Screening of varieties for mosaic resistance

The resistance of each variety was evaluated using severity data obtained from the field and the plants placed into different resistance categories using the method described by Khan and Boyd (1969). The varieties were grouped into two categories:

- Resistant varieties are those without disease symptoms or those that show mild symptoms of the disease. They have severity scores ranging from 0 to 2 and correspond to the following classes: 1-1.5 (resistant); 1.5 - 2 (moderately resistant);

- Sensitive varieties with moderately severe and severe attacks are those with scores ranging from 3to 5. Classes in this category are as follows: 2-3 implies moderately sensitive; 4 -5: are very sensitive (Khan and Boyd, 1969).

To determinate the relationship between the epidemiological and morphological variables studied on the one hand and to group the varieties into more or less homogeneous classes, on the other hand, we used the Principal Component Analysis (PCA) and the hierarchical numerical classification respectively

3.4. Correlation between disease severity and plant height

Correlation graphs were drawn to check linear relationships existing between severity index and height increment of plants and to establish any links with the results of PCA. This was important to verify if an increase in the severity index had any impact on the increase in height of the different varieties.

3.5. Data analysis

Analysis of variance (ANOVA) was performed on data obtained using the R software. Duncan test was used to determine the difference between averages the threshold of 5 %. Cluster analysis was carried out using community Analysis package software version 2015 (Henderson et *al*., 2002) and XLSTAT for principal component analysis.

RESULTS AND DISCUSSION

1. Morphological characteristics of local and improved varieties

Eighty-six (86) local varieties and seven (07) improved varieties were identified and characterized using their morphological parameters (Tables I and II). The names of the varieties listed are those used by farmers in the locality of study. In all plots, the common leaf color was dark green, average number of brancheswas3, the average length of the leave lobe was 16.46 cm, the average length of the petiole was 22 cm, while the mean number of lobes per leaf was 5 (Table I). For the improved varieties, in general, the leaf color was purple green, leaf shape was ovoid, average lobe length and petiole were respectively 14.88 and 16.71 cm and the average number of lobes per leaf was 4 (Table II).

Table I. Main morphological characteristics of local varieties studied

criteria / varieties (name and /or code)	Leaf color	Petiole color	Lobe form	Lobe height (cm)	Petiole height (cm)	Number of the lobes per leaf
Pola red beul / F 21	dark green	Light green	lanceolate	15	23	3
Tokbanbwgueive Dana / F17	dark green	Light green	lanceolate	14	15	5
Pola black-short / F21	purple	red	lanceolate	19.5	36	7
Pola black-long beul/ F21	purple	red	ovoïd	30	39	7
Gladys Dschang	dark green	red	ovoïd	17	22	5
Mabong Mekoul Sovokong l	purple	Darkred	lanceolate	14	30	7
Brown Stem, Yamben	green	Light red	ovoïd	12	10	5
Mani Mbong-Sangmelima	green-purplish	red	ovoïd	17	25	6
Pola black long beul	Dark green	red	ovoïd	16	17	7
Bout, Mpemzok	purple	light green	lanceolate	19	22	8
SawadaDigron	purple	Darkred	ovoïd	15	21	5
Gambada,Soagol	green-purplish	red	lanceolate	19	25	5
Balonkpong,Dana	light green	red	lanceolate	14	15	4
YaraAdinkoé	purple	red	ovoïd	14	25	5
Sweet cassava	green-purplish	Reddish-green	ovoïd	23	31	7
Gambada,Boumadjalé	dark green	red	ovoïd	14	26	5
NabongMekoul, Sovokongll	dark green	red	ovoïd	10	17	3
Six months Tiko. Lis	dark green	Light red	ovoïd	21	27	6
Akourakwa Mpemzok	green-purplish	red	ovoïd	16.5	15	3
Guge 2nd	dark green	Light green	ovoïd	14	11.5	3

2e - 9	green-purplish	red	ovoïd	14.7	15	3
Bitoto/ F17	dark green	green	ovoïd	11.5	11	4
Nkol- ossané	green	red	cylindrical	26.5	25	7
BalbineMeyosbben	purple	red	lanceolate	18	28.5	7
BititiBoumadjalé	green-purplish	Darkred	lanceolate	22	34	7
Ché 2nd / F4	green-purplish	red	ovoïd	15.5	25	6
Mdaga2nd – 3	green-purplish	Darkred	ovoïd	15	32	7
Mraheg 2nd - 2	green	red	lanceolate	17	21	5
GbeguedaGandoua	green-purplish	red	lanceolate	17.5	22,5	6
Moumpé Femelle Garoua Yara	green-purplish	red	lanceolate	19.5	26.5	7
Campo (Mvaa)-1	green-purplish	red	lanceolate	18	26	4
Badobo- Tikolo	dark green	green	ovoïd	17	27	7
Moan- Moan, NkolOsananga	green-purplish	light green	lanceolate	14.5	15	3
Mintourou- Mvaa II	dark green	red	lanceolate	16	19	3
Ngambada-Ngambada	dark green	red	lanceolate	14.5	17	4
Gbalonkpong-Gandong	dark green	green	ovoïd	13	16	4 - 6
Red petiole Bafia	green-purplish	red	lanceolate	15	23	5 to 7
AfoubaDovaye	green-purplish	red	lanceolate	18	28	6
Ntang Mvaa	green-purplish	red	ovoïd	19	29	6 to 7
Tougueda – Gbata / F16	dark green	green	lanceolate	14,5	14,5	4 to 6
Green petiole – Yambassa						

LiogoAdinkol/F10	purple	green	lanceolate	16	24	5 to 7
Red Petiole - Yambassa	green-purplish	red	lanceolate		21	7
Tuyobo- Bétani/F11	green-purplish	riddish-green	ovoïd	13	35,5	7
Gbafdougoa- Bata	green-purplish	red	lanceolate	14,5	14,5	3 to7
Red petiole- Binoun	purple	green	lanceolate	18	16	5
Fonctionnaire (Mekonkin)	green	red	ovoïd	16	26	5
Green petiole- Bokito	green-purplish	red	ovoïd	15	28,2	5 to 6
Ganbada	dark green	light green	lanceolate	11,5	10	3
Green petiole Bafia	dark green	green	ovoïd	12	16,5	3
Green petiole binoun	purple	green	ovoïd	9	20	7
Redpetiole-Bokito	dark green	riddish green	ovoïd	17,5	21,5	5
Damouna GRP / B8	green-purplish	red	ovoïd	17	25	7
Tymere- kournou / F1	dark green	red	lanceolate	19,5	27	7
Ntani-Koumou/ F1	purple	light green	lanceolate	16,5	17	3
Ntolo 1er - 20	green	green	ovoïd	13	11	3
Yoyolo-Ovangoull /F5	green-purplish	red	lanceolate	22,5	34	7
Akourou- Ovangoul	dark green	red	lanceolate	14	15,5	5
Noumpé Mal (Garoua) Yakol/F12	green	red	ovoïd	13	15	4 - 5
Aoa-koumou	green-purplish	red	lanceolate	14,5	14,5	3
Saa 1er /15	green-purplish	green	ovoïd	23	30	5
Mekinda 1er – 14	dark green	riddish green	ovoïd	17	19,5	5
Manioc Bassa 1er / 9	green-purplish	red	ovoïd	14	14	3
AyabBisoa	green	red	lanceolate	20,5	32	5 to 7
Campo(Mvaa)-2	dark green	red	lanceolate	18,5	32	6
Ntolbiko 1er / 6	green-	green	ovoïd	16,5	19,5	6

	purplish					
Akourou Ovangou	green	light green	ovoïd	11,5	12	4
Enouma Obokoé	green-purplish	red	lanceolate	17	21	5
Megnong Nkolo-Sanaga	green-purplish	red	lanceolate	19	23	6
Ntem I- Okoukouda	dark green	green	ovoïd	16,5	23,5	6
Ekwémé 1er -1	green	red	lanceolate	17	22,1	5
Campo Nkol-Ossam F18	dark green	green	lanceolate	12,5	10,2	3
Mbam 1er – 21	dark green	green	lanceolate	12,5	20,5	5
Ekékam I	green	green	ovoïd	14	20,5	6
Ekékam II	drak green	green	ovoïd	10,2	9,5	5
Manioc Bassa	dark green	light green	lanceolate	16,2	14	6
Owona Ekani	dark green	red	ovoïd	10	16	5
Mbida et Mbani	green	red	ovoïd	16	23	5 to 6
Manioc jaune	green	light green	ovoïd	13,5	17	5
Man Mbong (P.M.N. N)	dark green	green	lanceolate	18,5	20	5
Nnom Ewondo	green-purplish	red	lanceolate	12	16,5	5
Makoumba I	dark green	red	lanceolate	19,5	28,5	5
Ziéyabomedzé/ 001/ NN	dark green	red	lanceolate	23,2	36,5	6
Bitourou M. K. 1	green-purplish	dark red	lanceolate	25,8	43	5 to 6
Minbourou (BGL)	dark green	dark red	ovoid	15	15	6
Ntangna-red pétiole (OM)	green-purplish	red	lanceolate	14,6	21	5
Makoumba II(S P) Mefomo	green-purplish	riddish green	lanceolate	18,5	14,5	3
A lot bikon (N.O)	dark green	green	lanceolate	13	7	3
AfoboNkozoa	green-purplish	riddish green	lanceolate	17,5	12,5	3

Table II. Names and morphological characteristics of improved varieties

Varieties (name and/ or code)	Leaf color	Petiole color	Lobe form	lobe height (cm)	Petiole height (cm)	Number of the lobes per leaf
92 /0326	green-purplish	red	ovoïd	16	23	5
0110	dark green	light green	ovoïd	14	12	3
8034	green	green	lanceolate	16,2	19,5	3
8061	dark green	green	lanceolate	13,5	16	5
8017	green-purplish	green	lanceolate	14,1	18	3
Excel	green-purplish	red	ovoïd	13	15,5	3
champion	green-purplish	red	ovoïd	12,5	13	5

2. Incidence and severity of African cassava mosaic disease

The results show that the disease was present to varying degrees and varied across all varieties. Severity indices of 4 and 5 denote plants which showed high sensitivity to disease (fig.1). A range of plants showing the above-mentioned indices as *green petiole - Binoun* (67.00 ± 25.70); *Red petiole Yambassa* (60.33 ± 28.83); *Mintourou-Mvaa* II (63.93 ± 24.80) were recorded (Table III). However, very low values with a corresponding degree of severity of 1 were obtained for varieties *Nkolossane/18*(3.83 ± 0,620); *red Petiole Bafia* (12.00 ± 8.18) (Table III). These results indicate tolerance to African cassava mosaic disease (fig.1).

Fig.1. Different degrees of symptoms from 0 to 5 following Cours score

Analysis of the results showed that the rate and level of disease spread on the different varieties varied from one accession to another. The values ranged from 5.16% *(Nkolossane / 18*) to 86.00% *(Owona Ekani)* (Table III).

Table III. Variation of Incidence and severity of mosaic amongst the different local varieties

Varieties	Incidence (%)	Severity (%)
Pola red. Beul/ F 21	60,00 ± 24,55 abcde	39,33 ± 16,80 abcde
Tokbanwgueive Dana/17	32,88 ± 15,66 abcde	31,20 ± 14,26 abcde
Pola black short /F21	16,85 ±11,36 abcde	37,00 ±15,71 abcde
Pola black- long beul / 21	52,76 ±21,90 abcde	37,00 ±15,71 abcde
Gladys Dschang	73,00 ± 28,88 abcde	46,33 ±18,44abcde
Mabong Mekoul, Sovokong 1	38,33± 17,55 abcde	28,66 ±13,05 abcde
Brown Stem- Yamben	69,84 ± 27,74 abcde	41,73 ± 17,13 abcde
Mani mbong-Sangmelima	12,06 ± 10,85 de	37,00 ± 15,71 abcde
Pola black long beul	81,66 ± 31,75 abcd	59,60 ± 23,68 abc
Bout, Mpemzok	56,66 ± 24,28 abcde	30,33 ±23,57 abcde
Sawada Digron	71,00 ± 29,54 abcde	38,53 ± 17,78 abcde
Gambada,Soagol	47,00 ± 19,67 abcde	41,33 ± 16,80 abcde
Balonkpong Dana	82,33 ± 30,59 abc	36,33 ± 16,50 abcde
Yara Adinkoé	24,48 ± 13,15 abcde	28,00 ± 14,10 abcde
Sweet cassava	57,42 ± 24,90 abcde	51,00 ± 20,66 abcd
Gambada Boumadjalé	28,71 ± 14,78 abcde	20,66 ± 10,01 bcde
Nabong Mekoul Sovokong II	46,66 ± 20,20 abcde	41,00 ±17,34 abcde
Six months Tiko,Lis 2	56,00 ± 21,28 abcde	42,06 ± 18,22 abcde
Akourakwa, Mpemzok	71,00 ±29,54 abcde	28,66 ± 14,64 abcde
Guge 2nd	30,00 ± 15,00 abcde	31,46 ± 13,68 abcde
2e - 9	5,16 ± 8,51 e	3,83 ± 6,20 e
Bitoto/F17	23,81±12,68 abcde	20,66 ± 10,01 bcde
Nkol- Ossané/18	5,16 ± 8,51 e	3,83 ± 0,62 e
Balbine Meyosbben	24,81 ± 11,22 abcde	20,33 ± 10,50 bcde
Biti Boumadjalé	24,14 ± 12,22 abcde	29,40 ± 7,21 abcde
Ché 2nd /F4	13,33 ± 10,40 cde	20,33 ± 10,50 bcde
Madaga 2nd – 3	22,33 ± 11,67 abcde	29,00 ± 12,52 abcde
Mraheg 2nd-2	30,00 ± 15,00 abcde	20,66 ± 10,01 bcde
Gbegueda Gandoua	65,33 ± 39,11 abcde	26,60 ± 12,21 abcde
Moumpé Femelle Garoua yara	48,33 ± 17,55 abcde	27,00 ± 12,52 abcde
Campo (Mvaa)- 1	45,00 ± 22,91abcde	24,00 ± 11,00 abcde
Badobo-Tikolo	65,66 ± 38,55 abcde	34,93 ± 14,85 abcde
Moan-Moan Nkolosanaga	60,44 ± 24,91 abcde	42,40 ± 17,67 abcde
Mintourou-Mvaa II	70,66 ± 30,10 abcde	63,93 ± 24,80 ab
Ngambada-Ngambada	63,33 ± 25,65 abcde	26,93 ± 13,26 abcde
Gbalonkpong - Ngandong	38,00 ± 18,08 abcde	37,00 ± 15,71 abcde

Pétiole rouge Bafia	25,33 ± 14,50 abcde	12,00 ± 8,18 de
Afouba Dovaye	14,40 ± 10,45 bcde	20,00 ± 11,00 cde
Ntangna, Mvaa	83,33 ± 42,52 ab	20,66 ± 10,01 bcde
Tougueda-Gbata/F16	51,09 ± 24,63 abcde	24,66 ± 11,50 abcde
Green petiole – Yambassa	78,33 ± 37,52 abcde	44,33 ± 20,10 abcde
Libogo Adinkol/F10	80,66 ± 33,48 abcd	60,33 ± 26,83 abc
Tuyobo- Bétani/F11	25,33 ± 14,50 abcde	20,33 ± 10,50 bcde
Gbafdougoa-Bata-Bata	40,90 ± 18,00 abcde	31,46 ± 13,68 abcde
Red petiole-Binoun	57,00 ± 23,73 abcde	53,33 ± 21,77 abcd
Fonctionnaire (Mekonkin)	61,66 ± 28,43 abcde	30,26 ± 12,73 abcde
Green petiole- Bokito	82,66 ± 30,02 abc	33,66 ± 14,10 abcde
Gambada	81,00 ± 32,90 abcd	36,00 ± 17,34 abcde
Green petiole Bafia	63,33 ± 25,65 abcde	32,00 ± 14,10 abcde
Green petiole- Binoun	51,36 ± 21,68 abcde	67,00 ± 25,70 a
Red petiole- Bokito	45,00 ± 22,91 abcde	26,33 ± 13,57 abcde
Damouna-GRP/BB	71,00 ± 29,54 abcde	55,26 ± 22,56 abcd
Tymère-kournou/F1	74,16 ± 34,49 abcde	25,73 ± 12,32 abcde
Ntani-koumou/F1	41,29 ± 19,90 abcde	27,33 ± 15,17 abcde
Ntolo 1er- 20	65,33 ± 30,66 abcde	36,33± 16,80 abcde
Yoyolo-Ovangoul/F5	73,86 ± 30,27 abcde	46,33 ± 20,18 abcde
Akourou-Ovangoul	80,00 ± 34,64 abcd	48,00 ± 20,66 abcd
Noumpé Mal(garoua) yakol /F12	78,33 ± 29,29 abcd	36,66 ± 16,26 abcde
Aoa-koumou	52,00 ± 27,87 abcde	22,80 ± 11,60 bcde
Saa 1° /15	55,00 ± 22,91 abcde	31,46 ± 13,68 abcde
Mekinda 1er$_{-14}$	78,66 ± 36,95 abcd	44,33 ± 20,10 abcde
Cassava bassa 1er /9	62,33 ± 27,31 abcde	40,40 ± 19,33 abcde
Ayab Bisoa	23,14 ± 13,63 abcde	27,66 ± 14,64 abcde
Campo(Mvaa)- 2	41,29 ± 19,90 abcde	20,00 ± 11,00 cde
Ntolbiko 1er /6	56,66 ± 24,28 abcde	20,00 ± 11,00 cde
Akourou Ovangou	41,62 ± 19,37 abcde	27,66 ± 14,64 abcde
Enouma Obokoé	15,07 ± 9,68 bcde	20,00 ± 11,00 cde
Megnong Nkolo-Sanaga	53,22 ± 23,09 abcde	31,46 ± 15,28 abcde
Ntem I - Okouda	81,66 ± 31,75 abcd	20,33 ± 10,50 bcde
Ekwémé 1er- 1	47,00 ± 19,67 abcde	40,33 ± 18,44 abcde
Campo Nkol-ossam F/18	73,22 ± 31,40 abcde	30,00 ± 14,10 abcde
Mbam 1er - 21	80,00 ± 34,64 abcd	24,33 ± 12,01 abcde
Ekékam I	81,66 ± 31,75 abcd	58,46 ± 25,25 abc
Ekékam II	79,33 ± 35,79 abcd	46,33 ± 20,10 abcde
Cassava Bassa	50,88 ± 22,00 abcde	24,00 ± 12,52 abcde
Owona Ekani	86,00 ± 37,98 a	29,46 ± 13,68 abcde
Mbida et Mbani	5,20 ± 8,66 e	20,66 ± 10,01 bcde
Yellow cassava	75,16 ± 32,78 abcd	38,86 ± 17,23 abcde
Man Mbong (P.M.N.N)	20,50 ± 12,46 abcde	36,66 ± 16,25 abcde
Nnom Ewondo	51,06 ± 23,45 abcde	28,33 ± 15,71 abcde
Makoumba I	44,66 ± 23,45 abcde	25,06 ± 13,36 abcde
Ziéyabomedzé/001/NN	36,00 ± 17,29 abcde	25,06 ± 13,36 abcde
Bitourou M, K, 1	40,50 ± 20,07 abcde	22,20 ± 11,91 bcde

Minbourou (BGL)	26,00 ± 13,52 abcde	24,00 ± 12,52 abcde
Ntangna-red petiole. (OM)	75,83 ± 31,65 abcd	42,66 ± 17,89 abcde
Makoumba II (sp) Mefomo	55,00 ± 27,04 abcde	20,00 ± 11,00 cde
Alot bikon (N, O)	36,00 ± 17,29 abcde	24,33 ± 12,01 abcde
Afobo Nkozoa	25,33 ± 14,50 abcde	19,66 ± 11,50 cde

2.3 Incidence and severity of mosaic on improved cassava varieties

The behavior of CMV on the improved varieties was different from that of the local varieties. Of the 07 improved varieties tested, mosaic symptoms were recorded on three (8017, 8061, and 0110) with 40%, 37.2% and 37.4% severity respectively. However, there were no significant differences (p = 0,005)in disease severity between the three varieties. The incidence values were 4.2%, 38.4% and 37.4% indicating significant difference in the spread of the disease (p = 0,005). The four other varieties, namely Champion, Excel, 92/0326 and 8034, were resistant to CMD with no symptoms of disease visible on the leaves (Figure 2).

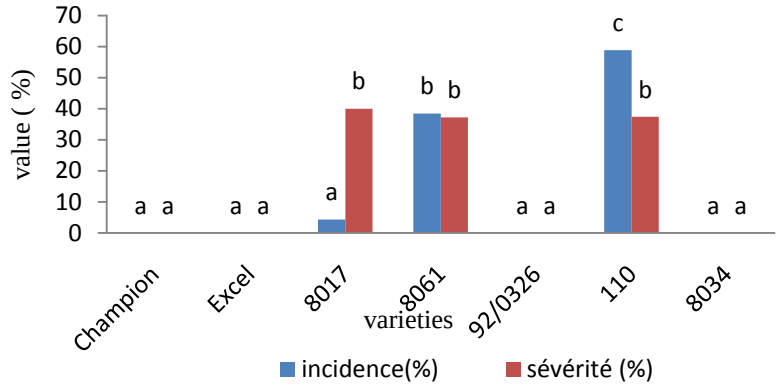

Fig. 2. Incidence and severity of CMD on improved varieties

3. Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC) of 86 local varieties

3.1. Distribution of variables on the first two axes of the PCA

The PCA constructed from the 6 variables related to severity and incidence of mosaic symptoms and the morphological characteristics (height, petiole length, lobe length, lobe number) indicated a good representation of the variables. It was done through the correlation circle, with most of the information on the total variability found on plane F1- F2 (67.68%). This corresponds to an almost heterogeneous spread along the F1 axes which contains

40.96% of the information on the morphological characteristics of the 86 local varieties of cassava and F2 26.72% of the information on the African cassava mosaic infection (fig.3).

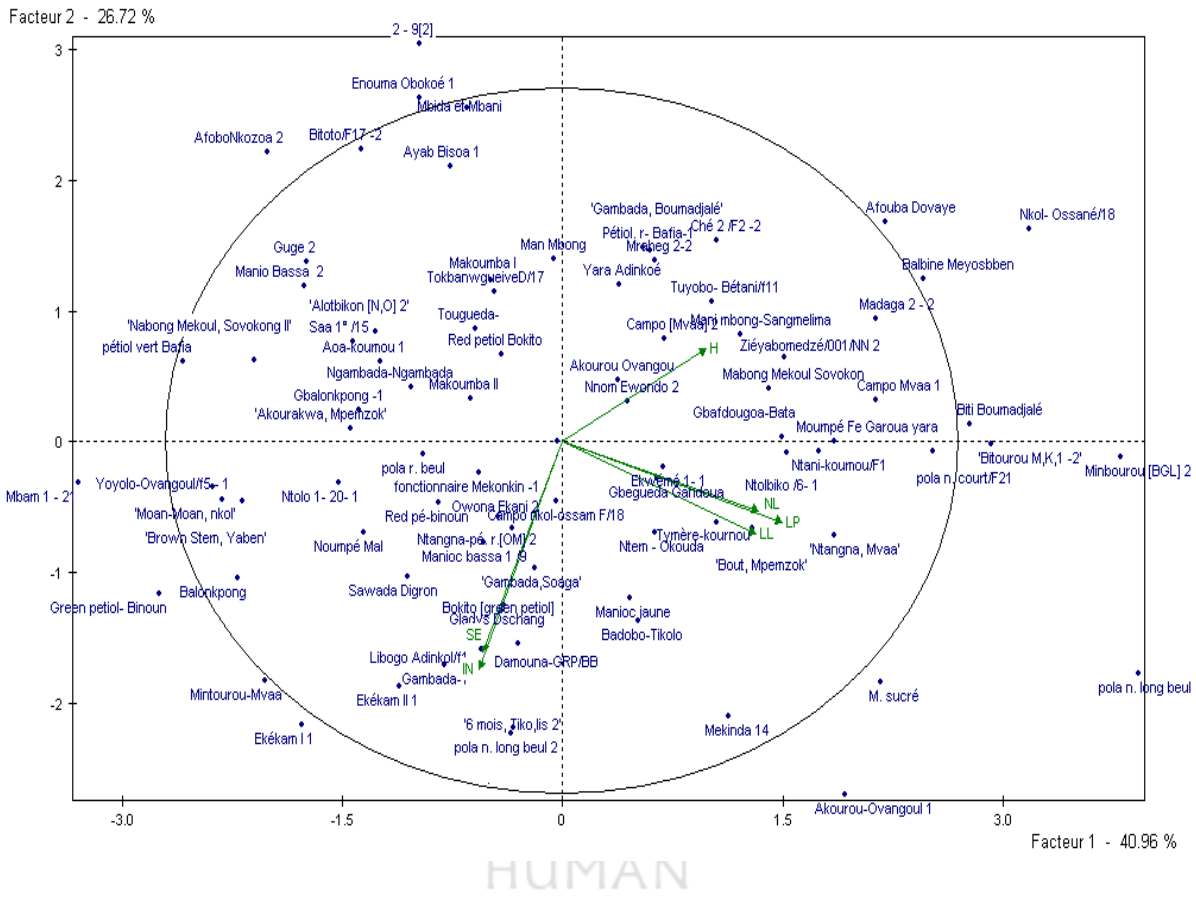

Fig. 3.Distribution of variables on axes 1 and 2 of the main component

From the genotypic configuration, axes 1 and 2 show the approximation between the varieties which are located at the same level on the first axis of the PCA and which consequently present a very strong similarity with the latter.

3.2. Discrimination of varieties into different groups

The different variables (severity, incidence, and morphological parameters) made it possible to discriminate the varieties and classify them into six distinct groups. Groups I, II, III, IV, V and VI have 30, 18, 23, 6, 4 and 4 varieties respectively (Table VI). ANOVA shows the difference between the different groups. UsingPCA, we obtained a dendrogram showing phylogenetic relationships as well as the level of resemblance between the 86 varieties of cassava tested for resistance. There was no significant difference between the genotypes of the same group, but significant differences were observed between genotypes from different groups (Fig 4).

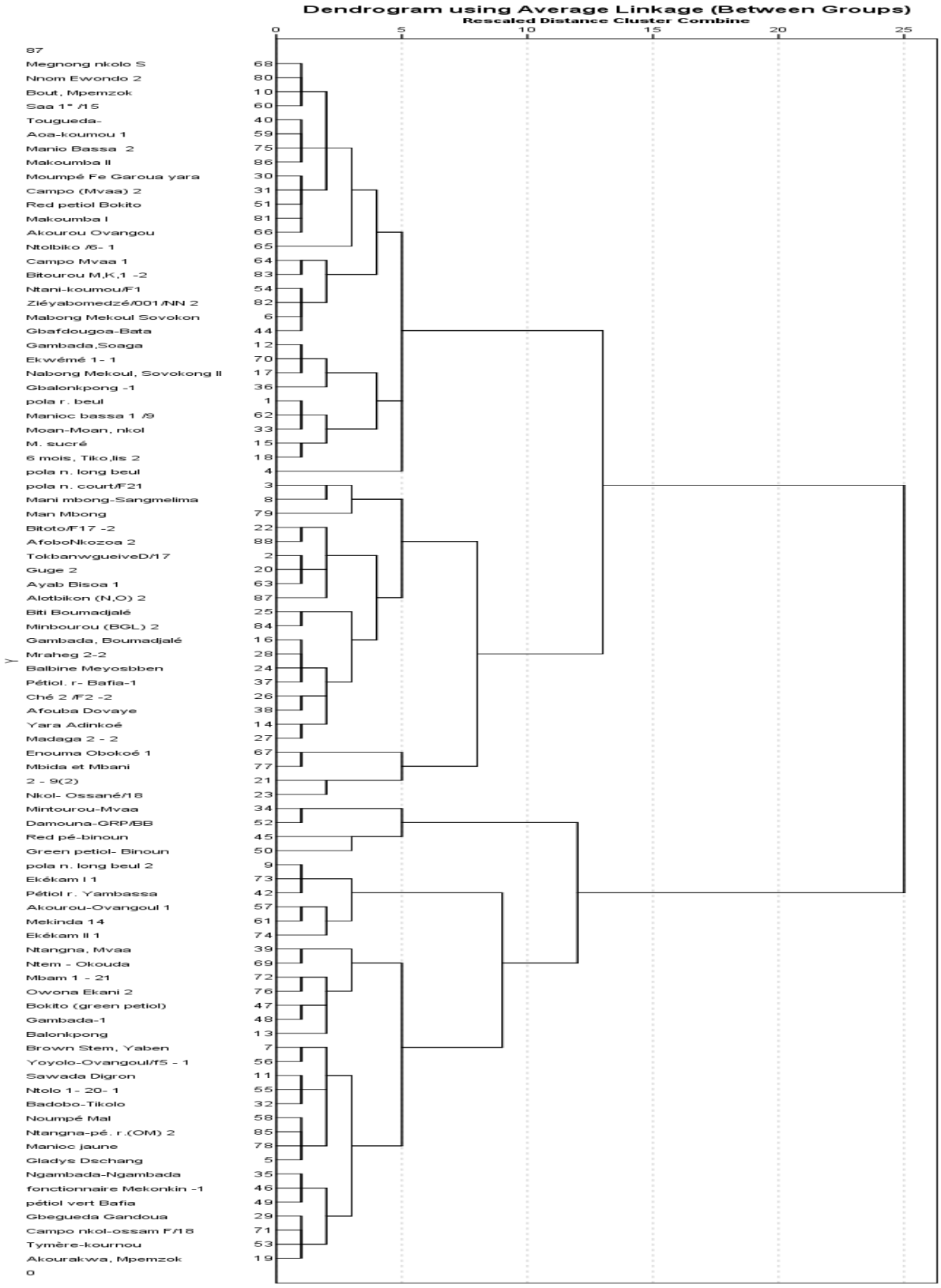

Fig.4 Dendrogram of approximation between screened cassava genotypes based on infection with CMD and morphological criteria.

Table IV. Grouping of cassava cultivars based on similarity

Varieties	Group	Varieties	Group	Varieties	Group
Pola red beul/F21 Pola black- long beul/F21 MabongMekoulSovokong I Bout, Mpemzok Gambada,Soagol Sweet cassava NabongMekoul sovokong II Six months Tiko Lis, Moumpé Femelle Garoua yara Campo (Mvaa) 2 Moan-Moan, nkol sananga Gbalonkpong -Gandong Tougueda-Gbata/F16 Gbafdougoa-Bata Red petiole Bokito Ntani-koumou/F1 Aoa-koumou Saa 1er /15 Cassava bassa 1er /9 Campo (Mvaa) 1 Ntolbiko1er /6 AkourouOyangou Megnongnkolo - Sanaga Ekwémé 1er Cassava Bassa NnomEwondo Makoumba I Ziéyabomedzé/001/NNN Bitourou M,K,1 Makoumba II(sp) Mefomo	**1**	TokbanwgueiveDana/17 pola black-short /F21 Mani mbong-Sangmelima YaraAdinkoé Gambada, Boumadjalé Guge 2nd Bitoto/F17 BalbineMeyosbben Bititi Boumadjalé Ché 2nd /F4 - Madaga 2nd-3 Mraheg 2nd-2 red petiole Bafia AfoubaDovaye AyabBisoa Minbourou (BGL) AfoboNkozoa Alotbikon (N, O)	**2**	Gladys Dschang Brown Stem - Yaben Sawada Digron Balonkpong Dana Akourakwa, Mpemzok GbeguedaGandoua Badobo-Tikolo Ngambada-Ngambada Ntang, Mvaa fonctionnaire (Mekonkin) Bokito (green petiole) Gambada Green petiole Bafia Tymère-kournou/F1 Ntolo 1er- 20 Yoyolo-Oyangoul/F5 Noumpé Mal (garoua) yakol/F12 NtemI - Okouda Campo nkol-ossam F/18 Mbam 1er - 21 OwonaEkani Yellow cassava Ntangna-red petiole. (OM)	**3**
Varieties	Group	Varieties	Group	Varieties	Group
Pola black long beul Red petiole Yambassa Akourou-Oyangoul Mekinda 1er- 14 Ekékam I Ekékam II	**4**	2e – 9 Nkol- Ossané/18 EnoumaObokoé Mbida et Mbani	**5**	Damouna-GRP/BB Red petiole-Binoun Green petiole Binoun Mintourou-Mvaa II	**6**

4. Correlation between mosaic severity and plant length growth

The results obtained showed different degrees of correlation existing between the parameters (plant height and disease). Strong correlations were observed for varieties *Nkol-ossané/18* and *Afouba Dovaye* amongst others, while lower levels of correlation were obtained with the variety *Pola black- long beul/F21* (Table V).

Table V. Correlation between disease severity and growth in plant length

Varieties	Coefficient of corrélation (r)	Observations
Pola black- long beul/F21	0,62	Very strong correlation
2nd-9	0,41	No correlation
Nkol-ossané/18	1	Very strong correlation
Glwadys Dschang	0,93	Very strong correlation
Afouba Dovaye	0,99	Very strong correlation
Red petiole Bokito	0,86	Very strong correlation

DISCUSSION

Our inventory of accessions enabled us locate 86 local varieties and 07 improved varieties. This wide range of local varieties from different localities highlights not only the importance of cassava in the eating habits of the population but also the ecological, demographic and human potential of this crop.

The incidence of CMD was shown to vary from one cassava genotype to another.

These results confirm the endemic nature of ACMV in the agro-ecological zone studied. Interestingly, some local accessions or genotypes were tolerant to African Cassava Mosaic Disease. Such instances of tolerance (resistance) were possibly due to the genetic properties of the plants. Disease incidence varied from 5.16 to 86.00%, depending on the cultivar. This variation in tolerance and susceptibility results from variations in the genetic makeup of the accessions. In addition, the cuttings used as planting material might have been infected cuttings since farmers have the habit of using cuttings from the previous planting season.

These results confirm those of Fauquet and Fargette (1990) who showed that a majority of cuttings used by farmers in West Africa already carry viral infections. Reports by Ambang et *al*. (2007 and 2009) showed that viral infections are conserved in planting material. The infections recorded on the cultivars would have resulted from primary infection of the cuttings planted, which would have been infected from the stems from which they were

taken. The observed variability in the incidence of disease from one variety to another in the same field could be due to their original environment (Ambang et *al*., 2016). The mosaic-resistant strains from the research centers showed symptoms of disease at varying intensities (4.28%, 37.2%, and 58.33% for 8017, 8661, and 0110, respectively). This is not very surprising because climatic changes have been shown to weaken the resistance of plant genes to ACMV in other improved viruses.

Disease severity varied according to the cassava cultivars at the study site surveyed. The average severity values (indices) for some of the cultivars were 1 and 2. These averages suggest tolerance of the cultivars to African cassava mosaic virus. This severity has two levels of resistance, including accessions with an index below level 3, which show the endemic nature of the African mosaic virus in cassava growing areas (Ambang et *al*., 2007).

The PCA confirmed the morphological variability between the different varieties, thus establishing the existence of a strong genotypic and phenotypic organization of the varieties tested. The varieties were also grouped according to their tolerance or sensitivity to CMV. PCA is a multi-variant analysis technique in which much information is obtained on the possible relationships between genotypes. Similar results have been reported by Aremu *et al.* (2007) on cowpea. The high coefficients of variation observed in this study for a significant number of characters indicate the presence of high heterogeneity within the varieties of cassava studied. The correlations indicated a linear relationship between the morphological and epidemiological traits studied. These correlations thus constitute an indispensable tool for geneticists in the choice of characteristics to be included in breeding programs.

The cluster analysis grouped the cultivars into 6 groups according to their similarity index using the morphological and epidemiological criteria: leaf color, petiole color, lobe number, lobe length, the height of the plant, incidence, and severity.

Botanical systematics is based on a hierarchical classification system based on similar attributes between species derived from common ancestors. Such classifications are natural because they are based on a natural system. Endogenous perceptions or folk classifications are often based on a single criterion, and the basis for vernacular names can be derived from a single attribute such as the origin of the plant material: the country, the tribe (cassava bassa), the name of a person (Owona Ekani), belonging to a locality (Soa1^{er}/ 15) and the maturation time of the crop (six months Tikolis). These results confirm those of Mbogne et *al*. (2008)

which showed that populations in different localities tend to assign different names to relatively similar cultivars.

The correlation between height and disease severity had a coefficient of variation as a function of cultivars. In other words, the degree of severity influences the growth of the plant in a variety range because the leaf area is reduced, hence reduced photosynthesis. However, growth in length of the plant was not affected by disease severity in some varieties. This could be explained by the origin of the cultivars and the presence of bioactive substances. In other words, some varieties would develop the disease at an earlier stage compared to others that do so late in the growing season. Plants with a severity index that does not affect growth constitute a guide for geneticists in the development of resistant varieties.

CONCLUSION

The present work on the screening of local cassava varieties provided an overview of 93 local and improved varieties on the resistance to ACM and the relationships between them by the morphological characteristics observed in the bimodal rain forest area of Cameroon. Thirty of the local varieties screened exhibited tolerance to mosaic and could potentially be used in breeding programs and also included in the national catalog of mosaic virus resistant cassava varieties. In addition, improved varieties such as 8017, 8061 and 0110 significantly lose their mosaic tolerance due to the fact that they become vulnerable or even susceptible to African cassava mosaic virus.

ACKNOWLEDGMENT

Thanks to Project IRAD/C2D/Cassava for the financial support to realize this work.

Thanks equally go to Dr. CHEWACHONG G. for translation of the manuscript from French to English.

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