Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Botany

Elixir Applied Botany 170 (2022) 56443 - 56451

ISSN: 2229-712X

Evaluation of the Severity of African Cassava Mosaic (ACMV) in Ten Cassava (*Manihot Esculenta* Crantz) Clones in Relation to the Bimonthly Leaf Harvest in Gbadolite, Democratic Republic of Congo

Ambwa, J.[1*], Idikodingo, T.[1], Molongo, M.[1], Mongbenga, G.[2], Likiti, O.[3,4], Mambokolo, C.[3,4], Diko, G.[3,4], Bulonza, J.C.[3,4], Empata, L.[3,4], Ebwa, J.[3,4], Ugencan, P.[3], Mamba-Mbayi, G.[3], Songbo, M.[1,3,4] and Monde, G.[3,4]

[1]University of Gbadolite, Faculty of Agronomic Sciences, Department of Plant Science B. P. 111 Gbadolite, Democratic Republic of Congo.

[2]Institut Supérieur Pédagogique de Molegbe, Department of Agro-Veterinarian B.P. 285 Gbadolite in the Democratic Republic of Congo

[3]Institut Facultaire des Sciences Agronomiques Yangambi B. P. 1232 Kisangani in the Democratic Republic of Congo.

[4]Central and West African Virus Epidemiology (WAVE) for Food Security, Institut Facultaire des Sciences Agronomiques Yangambi B. P. 1232 Kisangani, Democratic Republic of Congo.

ARTICLE INFO

Article history:
Received: 28 July 2022;
Received in revised form:
1 September 2022;
Accepted: 15September 2022;

Keywords
Bimonthly Harvest,
Severity,
ACM,
Yield,
Cultivars.

ABSTRACT

Cassava is a staple food in the world and in the Democratic Republic of Congo. A severe cassava epidemic would have long-lasting consequences for the population, which would probably result in malnutrition, reduced work performance, and possible migration to unaffected areas. This situation could be considered a disaster. The purpose of this study was to evaluate the severity of ACM and the bimonthly harvest on the leaf yield of ten cassava (*Manihot esculenta* Crantz) cultivars in Gbadolite, North Ubangi Province, Democratic Republic of Congo. The experimental design used was that of randomized complete blocks with 3 replications and 10 treatments, or 10 clones. Leaf yields in tons per hectare were 5.2 for cultivar Amuma; 4.1 for cultivars Mado and Moyindo; 3.9 for cultivar TME 419 or Obama; 3.8 for cultivar Nganza; 3.1 for cultivar RAV; 2.9 for cultivars Badiya and Dabeke; 2.7 for cultivar Khadafi and 2.0 for cultivar Yasegumba. MAM infection levels were in the range of 1 for cultivars Amuma and Dabeke; 2 for cultivars Moyindo, TME 419, and RAV; 3 for cultivar Yasegumba; and 4 for cultivars Badiya, Khadafi, Mado or Madame, and Nganza. The one-way analysis of variance and Duncan's test at the 5% probability level showed a significant difference. Tukey's post hoc test grouped cultivars according to the level of ACM infection. These results certify the level of severity of this virus in this province; for this reason, it is advisable to consider the control of this virus by popularizing resistant varieties and adequate cultivation techniques related to it.

Introduction

Problem, justification and context of the study

Cassava is considered the fourth most important crop in terms of its contribution to the world's diet after rice, wheat and maize. It is produced and used in human food on all five continents, except Europe, but it is of economic as well as food importance. Cassava roots are mainly produced in Africa (47.8%), Asia (33.2%) and South America (18.2%); other regions of the world (Oceania, Central America) contribute less than 0.8% to world production [1].

In the Democratic Republic of Congo, cassava is one of the most important crops and constitutes the staple food for at least 70% of the population thanks to its various parts, notably the leaves and tuberous roots, which ensure food security[2,3,4].

The leaves represent one of the good sources of the least expensive proteins, vitamins and minerals. It is noted that they contain about the same amount of protein as egg, which allows them to compete with some vegetables and staple foods[5,6].

In tropical countries, cassava, once dried, yields flours or starch plugs that provide more than 1 U.F. per kg. It is one of the roots offering energetic, palatable and refreshing foods, which contribute to the fattening of domestic animals[7,8].

The local cassava market is one of the most important in North Ubangi, in the town of Gbadolite and its surroundings. Indeed, cassava (leaves and roots) is the main food for most local populations as it is consumed in several forms including vegetables, cooked or raw tubers (songo), fried (ngosi), kneaded flour (fufu), pounded compact mix (kutubon), and pounded with cooked plantains (lituma) and chikwangue [9,10].

Despite its importance, this crop is subject to several production constraints including diseases and pests. Among the diseases, African cassava mosaic (ACM) is an important disease in the production area.

Tele: (+243) 813 640 190
E-mail address: molongobeni@gmail.com

This foliar virosis depresses photosynthetic efficiency, deforms leaves and reduces their surface area, resulting in a significant drop in tuber and leaf yields of up to 90% depending on the severity. Cassava farmers, most of whom are unaware of the existence of the disease, have no method of combating it and thus complain about the situation [11, 12, 13, 14].

This disease was first described in East Africa, particularly in Tanzania. The virus responsible has been characterized. It belongs to the group of Gemini viruses transmitted in the intertropical zone by the white fly (Bemisia tabaci). Its presence has been reported in several African countries. The six virus strains ACMV, EACMV, EACMCV, EACMZV, EACMMV and EACMZV are distinct and currently circulating in Africa1[5].

This epidemic is severe and would leave lasting socio-economic consequences among the population, which would likely include malnutrition, reduced work performance and income, and possible migration to unaffected areas. This situation could be considered a disaster.

Several control methods and techniques to mitigate the severity of this virus have been considered, including the use of resistant and healthy varieties, adherence to the agricultural calendar, phytosanitation, and cross protection [16,17,18,19]. Although these measures, the disease continues to worsen and spread and there is a need for research related to this disease.

This study is the first evaluative investigation of this viral epidemic in Gbadolite in the province of North Ubangi or Northern Democratic Republic of Congo. It joins related studies to assess the level of infection of African cassava mosaic (ACM), to study the relationship between the level of infection of this virus with the yield of bimonthly harvested leaves and to judge the behavior of cultivars vis-à-vis this disease under the agro-ecological conditions of this agricultural region.

This research answers the main question: What is the level of severity of ACMV on local and improved cassava cultivars under the agro-ecological conditions of Gbadolite?

Specifically, to answer the following questions:

Can high-severity cultivars give high leaf yields?

Can spacing of leaf harvesting be a strategy for mitigating the severity of AMD and consequently improving leaf yield in Gbadolite?

The main hypothesis was that local cultivars would be more infected than improved cultivars.

The following specific hypotheses were tested:

Cultivars with high AMD severity would have low leaf yield.

By spacing successive picks by two months, yield of tender shoots would be higher than with monthly picks.

The overall objective of this study was to evaluate the level of ACMV and the influence of bimonthly harvesting on leaf yield of 10 cassava cultivars under the agro-ecological conditions of Gbadolite.

The specific objectives were to evaluate the severity of ACM in the 10 varieties under study; to quantify production as a function of MAM severity and to assess the decrease in leaf yield resulting from different levels of infection of the crop by the virus.

Materials and Methods

Study Environment

This study was conducted in Gbadolite, at the 50 villas, in the Pangoma district. The GPS coordinates were as follows: Latitude North 4° 15' 45' and Longitude East 20° 59' 14', with an altitude of 392.87; accuracy: 4 m. The period of the experiment was from May 12 to November 12, 6 months of testing.

Figure 1 shows the town of Gbadolite. The town of Gbadolite has an Aw2 climate according to the Köppen classification. The average annual temperature is 28°C and rainfall is relatively abundant with an annual average of over 1600 mm. The insolation is low with 45% of total radiation [20].

The soil is of the clayey-sandy type. The vegetation used to be an equatorial evergreen rainforest, but under anthropogenic action, it has been replaced by a savannah where we find: Imperata cylindrica, Penisetum spp, Chromoleana odorata, Panicum maximum [9].

The biological material used for this study consisted of cuttings of 10 local and improved cassava cultivars obtained respectively from farmers' fields and from agri-propagators in the city.

The experimental set-up used was that of complete randomized blocks with 3 replications and 10 treatments, including T1: Amuma (improved bitter variety); T2: Badiya (local sweet variety); T3: Dabeke (local bitter variety); T4: Kadafi (local bitter variety); T5: Mado or Madame (local bitter variety); T6: Moyindo (local bitter variety); T7: Nganza (local bitter variety); T8: TME 419 or Obama (improved sweet variety); T9: RAV (improved bitter variety and T10: Yasegumba (local sweet variety).

A potential area of 3600 m2 or 0.36 ha was developed and 2100 m2 or 0.21 ha was planted. The 20 cm long cuttings were planted at a distance of 1 m x 1 m. A population of 50 individuals per treatment and a sample of 20 individuals were retained.

Observations were made on vegetative parameters such as recovery rate, crown diameter, plant height, number of stems per stump; while the yield parameter was leaf yield (in t/ha) and the pathological parameter on the severity of African cassava mosaic disease (AMD). The severity index scale or COURS symptom severity index, by macroscopic technique, led to an assessment of the degree of disease severity on the plants[21].

The Symptom Severity Index (SSI) scale ranges from 0 to 5 and is presented in Table 1.

The data collected were analyzed using IBM SPSS Statistics 20 software. Statistical analyses were done using 1 SE ANOVA and Tukey's post hoc test for difference in significance between treatments at the threshold of $p < 0.05$[22].

Figure 1. Map of the location of the Gbadolite site. Gbadolite MAP of the Gbadolite study area.

Table 1. The Symptom Severity Index (SSI) scale

Levels	Images	Symptoms
Level 0		Healthy plants or without apparent symptoms
Level 1		Yellowish spots covering 1/5th of the leaf blade or a light mosaic
Level 2		The spot covers half of the blade, appearance of the leaf deformations or a moderate mosaic
Level 3		Affected leaves deformed, partially curled up or strong mosaic
Level 4		Nearly all leaves curled up, reduced vegetative apparatus or severe mosaic
Level 5		Leaves reduced to 1/10th of their surface, atrophied branches, the plant withers and dies within a few months or very severe mosaic

Results

Recovery Rate (%)

The recovery rate was sampled and the results are recorded in Figure 2.

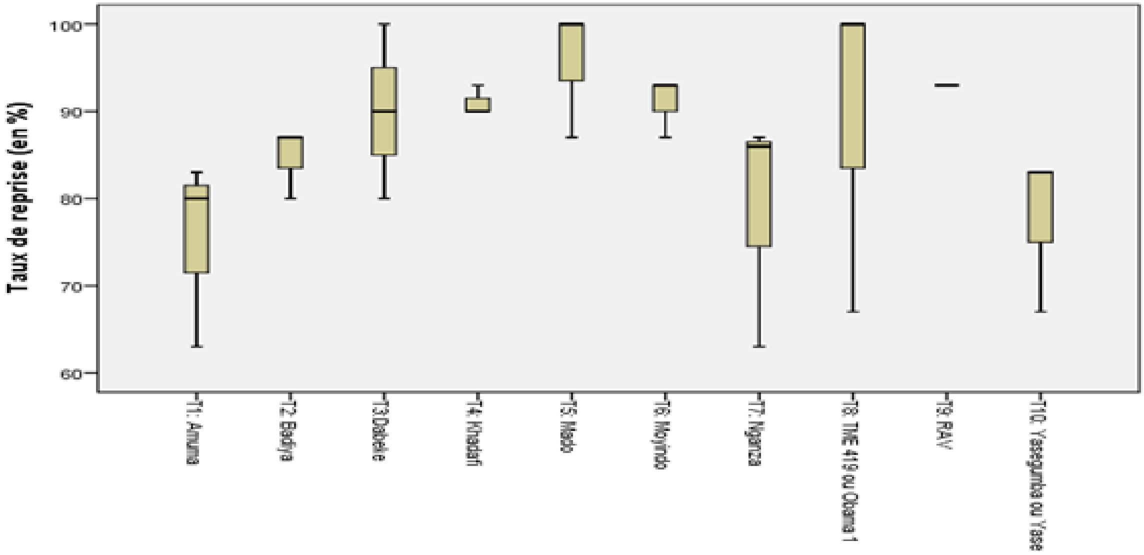

Figure 2. The recovery rate

The results of this figure show that the recovery rates were 75.5%, 84.4%, 90.0%, 91.1%, 95.5%, 91.1%, 78.9%, 88.9%, 73.3% and 77.7% for the cultivars Amuma, Badiya, Dabeke, Kadafi, Mado or Madame, Moyindo, Nganza, TME 419 or Obama, RAV and Yasegumba respectively, under the agro-ecological conditions of Gbadolite.

Diameter at the collar

Data related to crown diameter were collected and the results are presented in Figure 3.

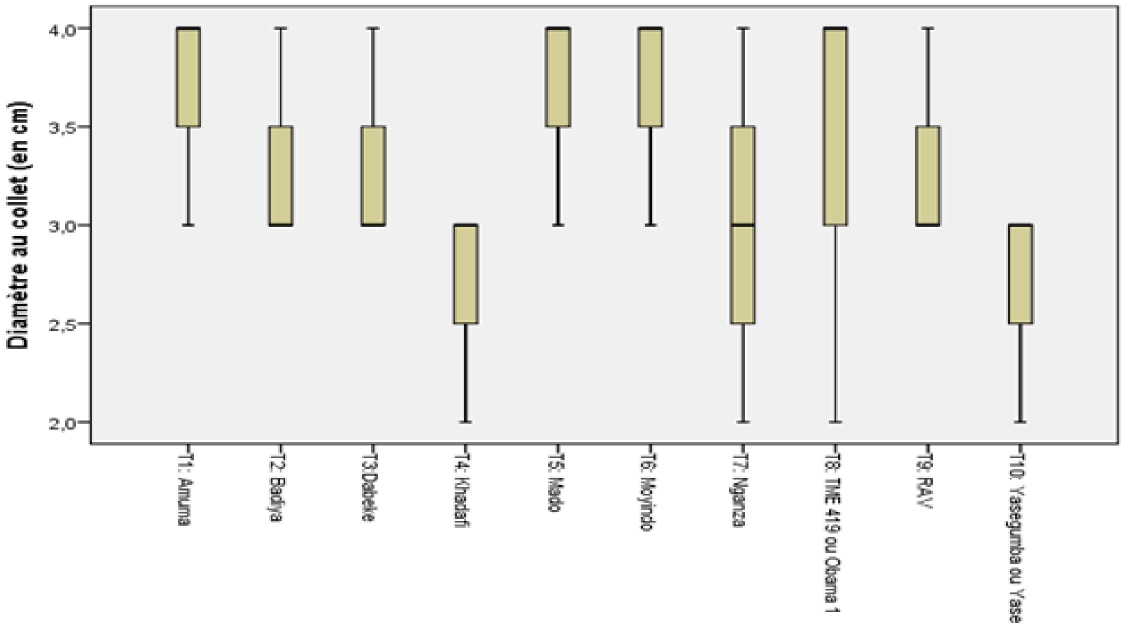

Figure 3. Diameter at the collar (in Cm).

It follows from Figure 3 that the diameters were in the order of 3.9 cm; 3.3 cm; 3.2 cm; 2.7 cm; 3.5 cm; 3.5 cm; 3.2 cm; 3.3 cm; 3.6 cm and 2.8 cm for the cultivars Amuma, Badiya, Dabeke, Kadafi, Mado or Madam, Moyindo, Nganza, TME 419 or Obama, RAV and Yasegumba respectively.

Plant height

The results related to the height of the plants are recorded in figure 4.

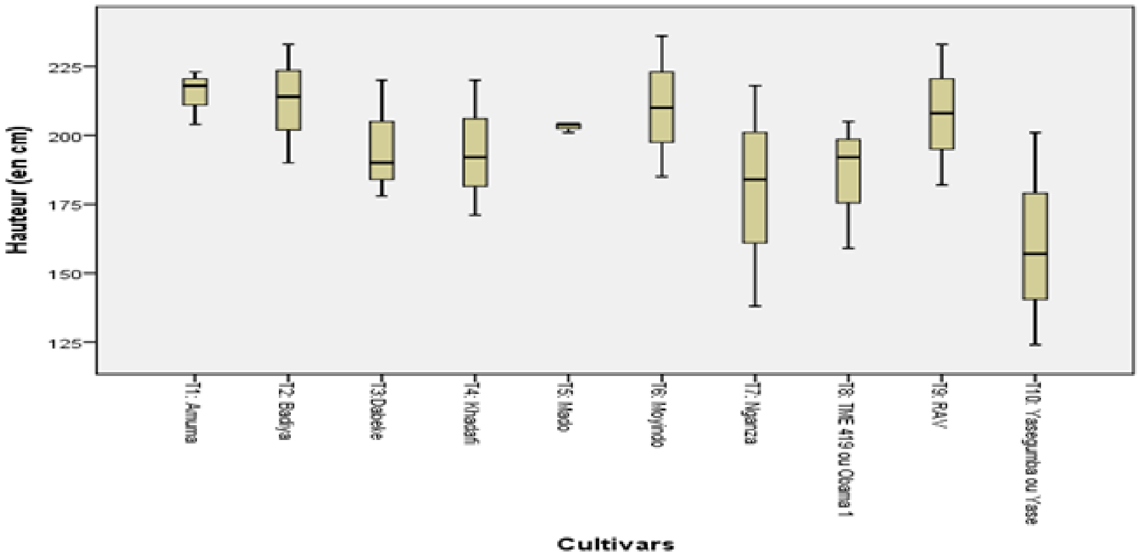

Figure 4. Plant height (in Cm).

Looking at Figure 4, the average plant heights range from 160.6 to 219.9 cm.

Number of stems per stump

The number of stems per stump harvested is presented in Figure 5.

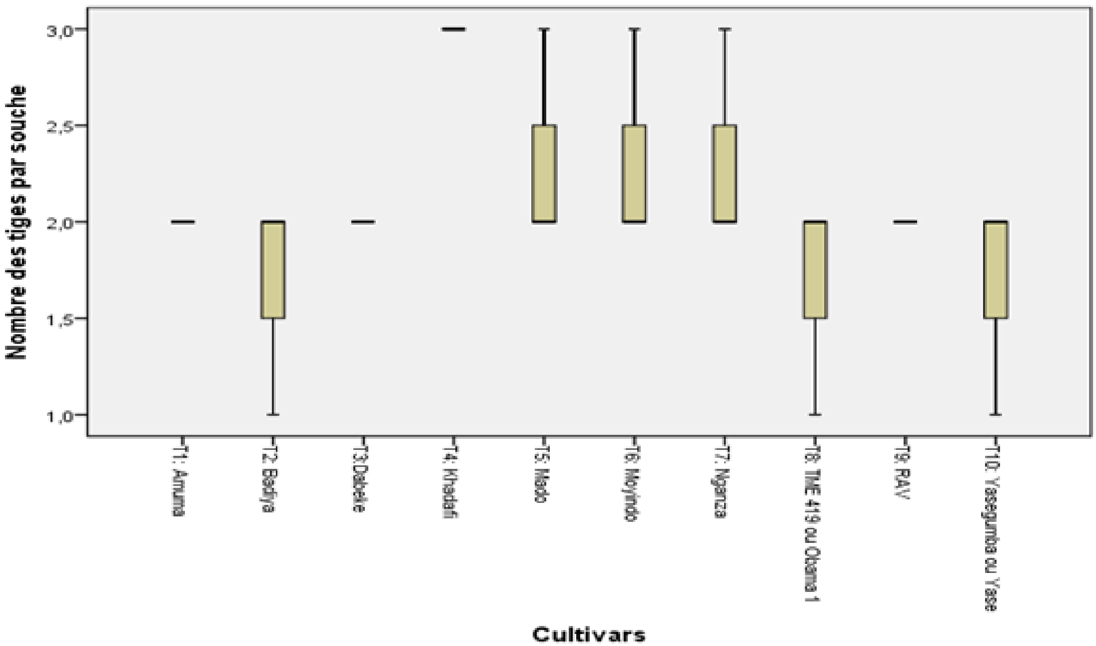

Figure 5. Number of stems per strain.

In the light of the results in Figure 5, averages ranked in descending order from 1 to 3. Only the variety Khadafi which gave more branches than the others.

Cumulative leaf yields in tons per hectare

The plot weight data of the leaves were extrapolated to tons per hectare and the results were recorded in Figure 6.

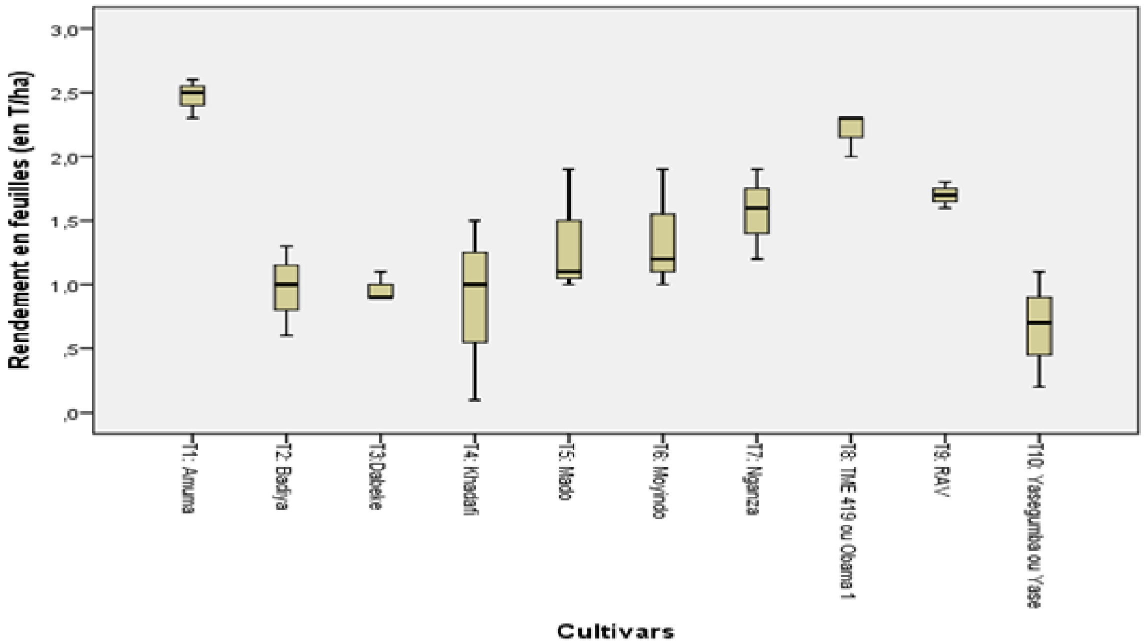

Figure 6. Cumulative leaf yields in tons/ha.

From the results obtained during this study, it can be seen that yields in tons per hectare of leaves varied according to cultivars, including 5.2; 2.9; 2.6; 4.1; 4.1; 3.8; 3.9; 3.1 and 2.0 for the varieties Amuma, Badiya, Dabeke, Kadafi, Mado or Madame, Moyindo, Nganza, TME 419 or Obama, RAV and Yasegumba respectively.

As for leaf yield, the single-criteria analysis of variance of classification without sampling (ANOVA 1 SE) at the 0.05 probability level showed that there is a significant difference and Tukey's post hoc test yielded the following conclusion: T10 T4 T2 T3 T9 T8 T7 T5 T6 T1. Thus, in terms of leaf production as a vegetable under Gbadolite conditions, the most productive cultivar was the improved cultivar Amuma; then the local bitter cultivar Moyindo which is not different in leaf production potential with the cultivars Mado or Madame, Nganza and TME 419 or Obama ; after the cultivars RAV, Dabeke, Badiya and Khadafi which are different with the cultivar Yasegumba which gives less leaves but a sweet tuberous root very appreciated by the natives.

Level of infection

The data related to the level of infection were observed and the results are shown in Table 8.

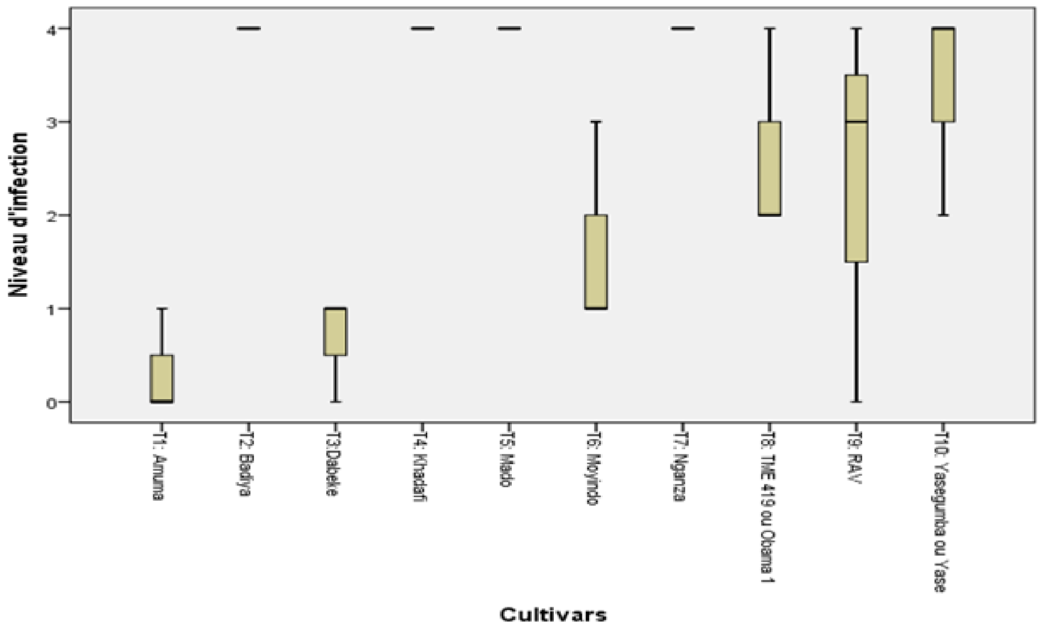

Figure 7. Level of infection.

From the results in Figure 7, it appears that the level of infection of ACM under Gbadolite conditions was about level 1 for cultivars Amuma and Dabeke; level 2 for cultivars Moyindo, TME 419 or Obama and RAV; level 3 for cultivar Yasegumba and level 4 for cultivars Badiya, Khadafi, Mado or Madame and Nganza under agro-ecological conditions of Gbadolite. Based on these results, it was observed that this virus has not yet reached level 5.

As for the level of ACM severity, the single-criteria analysis of variance classification without sampling (ANOVA 1 SE) and Duncan's test yielded a significant difference at the 5% probability level. Tukey's post hoc test yielded the following conclusion: T1 T3 T6 T9 T8 T10 T2 T4 T5 T7. Thus, the level of infection of this virus was significant in the cultivar Nganza, local and bitter but this severity was similar to the cultivars Mado or Madame, Khadafi, Badiya, Yasegumba, TME 419 or Obama, RAV and Moyindo but different from cultivars Dabeke and Amuma which presented a virus at level 1

Discussion

Considering the extreme high (95.5%) recovery rate, it can be observed that the recovery rate varied proportionally to the cultivars under the conditions of this study; nevertheless, the decrease in recovery rate for some cultivars is attributed to the attack of termites that constitute a scourge in this part of the Democratic Republic of Congo, especially during periods of rainfall disturbance.

The collar diameter of cultivars ranged from 2.6 to 3 cm, the recommended threshold for basal size for cassava stem selection in the Democratic Republic of Congo[23].

The height of some cassava varieties used in this study was less than or equal to 182.83 cm and 215.39 cm, an elongation that was not limited by the harvesting process in this study. This architecture falls within the 2 to 3 m height range[24, 25]. This performance of the plant proves that it was put in the right edaphoclimatic conditions adequate for its physiology on the one hand; on the other hand, it certifies that the bimonthly harvesting does not affect growth too much because it offers the plant a period of resilience and biochemical balance. Considering the diameter at the collar and the height of the plants, it appears that the cultivar Amuma is the most vigorous, followed by RAV and Mado or Madame and Moyindo among the cultivars under experimentation.

The leaf yields in tons per hectare were between 2.0 and 5.2. In view of the above, the best varieties to produce the leaves as vegetables were Amuma, Moyindo, Mado or Madam, Nganza and Obama or TME 419 under Gbadolite conditions.

These yields were less than 5.58 and 9.54T/ha, the yields recorded when harvesting bimonthly on 7 clones (82/255; 82/578; F150; F100; 30085/28; 02864; Mpelolongi) in Bas-Congo17. But less than 11.5T/ha in fresh leaves when harvesting at two-month intervals on the TMS 30211 variety[12].

This situation is justified by the differences in genetic potential between the varieties linked to the development of branches, several branches, erect stems, the ability to produce secondary and tertiary regrowth after harvesting the leaves, as well as to the growing conditions, in this case the quantity and distribution of rainfall, soil fertility and the level of secondary infection.

The coefficients of variation were more than 30% in relation to this parameter, which shows that the data were generally heterogeneous. Thus, the distribution of this virus within the population was variable and according to its concentration on the cutting. In general, the degree of infection of ACM under the agro-ecological conditions of Gbadolite, whatever the cultivar, was limited to Level 4, which means a strong mosaic.

Based on these results, the varieties experienced a level of mosaic from light to severe; the cultivars Amuma and Dabeke experienced light mosaic, the local cultivar Moyindo and the improved cultivars TME419 or Obama and Rav experienced moderate mosaic, the cultivar Yasegumba experienced strong mosaic, and severe mosaic collapsed the cultivars Badiya, Khadafi, Mado and Nganza.

During this study, no variety remained free from the virus, even those presumed to be improved and resistant. This aspect is justified by the presence and pressure of the population dynamics of Bemisi tabaci, the vector agent of this disease, and the weeds that surround the fields constitute the shelter of these whiteflies. However, no cultivar reached level 5 or very severe mosaic under the agro-ecological conditions of Gbadolite [26,27].

It is reported that the bimonthly harvesting technique mitigated the severity of the disease, thus these results confirm the thesis that regular leaf picking increases the severity of ACM because it favors the emission of young shoots, the site of multiplication and accumulation of virus; however, its spacing decreases the severity of this disease because the emission and development of major leaves constitute a bottleneck against the virus [19,28].

It was observed that local cultivars, namely Badiya, Khadafi, Mado or Madame and Nganza which are local cultivars showed higher severity than improved cultivars namely Amuma, TME419 or Obama and Rav. The improved cultivars showed moderate mosaic; this observation corroborates the thesis that the improved varieties show a trace severity of ACM in contrast to the local cultivars that show severe mosaic due to the absence of a resistance gene [6, 29].

It was stigmatized that leaf production was proportional to the severity of the disease, for this reason, susceptible varieties gave a lower yield than resistant varieties. The conclusion that ACM is a limiting factor in cassava leaf production according to the degree of infection assessed in IGS is supported by the fact that it deprives the leaf surface[15,30].

It appears from this study that regardless of the severity of the disease on the cassava cultivars under experimentation, some local cultivars presumed to be susceptible to the disease gave similar yields to the improved cultivars and a corresponding severity to the resistant cultivars under the agro-ecological conditions of Gbadolite in North Ubangi, Democratic Republic of Congo. This proves that these improved cultivars have lost the resistance mechanism to ACM.

Conclusion and Suggestions

This study was conducted to test the hypotheses that local cultivars are more infected than improved cultivars, that leaf yields are proportional to the severity of AMD, and that by spacing successive harvests by two months, yields of tender shoots are improved and the degree of disease is reduced. In addition, it constitutes a state of the art of this virus, a source of fundamental information on this epidemic and a dashboard of the actors of the viral disease unit in the North of the Democratic Republic of Congo.

For this purpose, 10 cultivars were put in experimentation and the results suggest the following

Yields in tons per hectare of leaves varied according to the cultivars and were recorded as 5.2 for the cultivar Amuma; 4.1 for the cultivars Mado and Moyindo; 3.9 for the cultivar TME 419 or Obama; 3.8 for the cultivar Nganza; 3.1 for the cultivar RAV; 2.9 for cultivars Badiya and Dabeke; 2.7 for cultivar Khadafi and 2.0 for cultivar Yasegumba; among the best leaf-producing cultivars, Amuma, Moyindo, Mado or Madame, Nganza and TME 419 or Obama were selected.

ACM infection levels under Gbadolite conditions were in the order of 1 (cultivars Amuma and Dabeke); 2 (cultivars Moyindo, TME 419 and RAV); 3 (cultivar Yasegumba) and 4 (cultivars Badiya, Khadafi, Mado or Madame and Nganza) under agro-ecological conditions of Gbadolite. The threshold of severity 5 was not reached.

Cassava being one of the crops of socio-economic and scientific importance, in view of these results, the following recommendations were formulated to sensitize farmers on the disease, to popularize resistant and productive materials; to proceed with the inventory of cultivated clones and with studies related to the physical-morpho-agronomic characterization of the cultivars adopted in this agricultural zone in order to detect cassava ecotypes with ACM resistance genes; to evaluate the incidence and severity of ACM in the fields; to evaluate the incidence and severity of ACM on tuberous root yield; to compare the impact of monthly, bimonthly, quarterly and semi-annual harvests on the incidence and severity of ACM; to study the importance of vector (Bemisia tabaci) population dynamics on the incidence and severity of ACM in the agrosystems of Gbadolite and North-Ubangi

References

1 Treche S. Importance du manioc en alimentation humaine dans différentes régions du monde. Transformation Alimentaire du Manioc. *Editions ORSTOM. See discussions, stats, and author profiles for this publication at : https://www.researchgate.net/publication/32972726.1995.*

2 Muyolo G. Situation actuelle des principales maladies du manioc au Zaïre et progrès réalisés dans leur contrôle, In séminaire sur les maladies et les ravageurs des principales vivrières d'Afrique centrale. *Place du champ de mars 5, Bruxelles (Belgique). 1987 ; 197-200.*

3 Walangululu M. La recherche des mécanismes de résistance de quelques variétés de manioc à l'acarien vert *Monochellus terajoa* (Bondar). Thèse de Doctorat inédite, *IFA-Yangambi. 1991 ; 3-14.*

4 Mahungu NM, Tata Hangy KW, Badiaka SM, Frangoie A. Multiplication de matériel de plantation de manioc et gestion des maladies et ravageurs. Manuel de formation destiné aux agents de terrain, *Institut International d'Agriculture Tropicale (IITA). 2014 ; 44.*

5 Adrian J, Frangne R. La science alimentaire de A à Z. Technique et documentation *LAVOISIER, France. 1986 ; 218.*

6 Kadima N, Munganga G, Bulubulu O, Mutambe, SND. Incidence et sévérité de la mosaïque africaine de manioc dans les champs et les jardins de case à Kinshasa (République Démocratique du Congo). *Tropicultura, 2017, 35, 3, 173-179*.

7 Besse J. L'alimentation du bétail, *Bussière, Saint-Amand (Cher), Paris. 1969 ; 365*.

8 Massamba, Treche. Transformations traditionnelles, formes de consommation et de commercialisation du manioc en milieu rural Congolais *in* Tropical root crops intenational society for tropical root crops (ISTRC) Africa brand. *Ibadan, Nigeria. 1989 ; 203-209.*

9 Molongo M, Ngbolua KN, Monde G, Magbukudua M, Ngemale G, Malomalo M, Shabani W, Mwanza B, Aaron L, Pambu. Effect of Sample Cuttings Area on The Cassava (*Manihot esculenta* Crantz var. *Rav*) Tuber Yields Under Agroecological Conditions of Gbadolite City, Democratic Republic of The Congo. *Journal homepage: http://scienceq.org/Journals/JABZ.php. Journal of Advanced Botany and Zoology Volume 2/ Issue 4 ISSN: 2015; 2348 – 7313*.

10 Magbukudua M, Molongo M, Monzanga D. Bases motivationnelles de la préférence alimentaire de manioc (*Manihot esculenta* Crantz) à Gbado-lite, RD Congo *in Annales de la Faculté des Sciences Agronomiques, Institut Facultaire des Sciences Agronomiques « IFA » Yangambi. Volume 4 ©2015 ; 218-230.*

11 Buyckx EJE. Précis des maladies et insectes nuisibles rencontrés sur les plantes cultivées au Congo, au Rwanda et au Burundi. 1962 ; 478-480.

12 Dahniya MT. Effet de l'effeuillage et de l'écimage sur les rendements en feuilles et en racines du manioc et de la patate douce. Plantes-racines tropicales : Stratégies de recherches pour les années 1980. Compte rendu de premier symposium triennal sur les plantes-racines de la société internationale pour les plantes-racines tropicales. *Direction Afrique 8-12 septembre 1980 Ibadan, Nigeria ; 145-150*.

13 Bakelana Z. Les facteurs déterminants l'abondance du vecteur mouche blanche (*Bemisia tabaci*, Homoptera : Aleyrodidae) et les types des virus sur le manioc en R.D. Congo. *DES/DEA, Faculté des Sciences Agronomiques, Département de Phytotechnie, Université de Kinshasa. 2010 ; 127*.

14 Monde K. Etude de virus de la mosaïque Africaine du manioc par comparaison des gènes AC4. *D.E.S, Université Catholique de Louvain. 2005 ; 45.*

15 Zinga I, Nguimal CR, Lakouetene DP, Konate G, Kosh Komba E, Semballa S. Les effets de la mosaïque africaine du manioc en République Centrafricaine. The impacts of African cassava mosaic in Central African Republic. *Geo-Eco-Trop, 2008, 32: 47– 60.*

16 Lepoivre P. Phytopathologie. *Ed. De Boeck Université, Belgique. 2003*.

17 Mahungu M., Ndombo D, Bidiaka M, Tubanza S. Sélection du manioc pour la production en feuilles. Tropical root crops. Procedings of the fourh triennal symposium of the international society for tropical root croops Africa (ISTRIC-AF) *Kinshasa 5-8 Décembre, 1992; 125-128.*

18 Monde G. Epidémiologie, diversité génétique et phylogéographie des virus de la mosaïque africaine du manioc dans la région de Yangambi en République Démocratique du Congo. Thèse de doctorat, Faculté d'ingénierie biologique, agronomique et environnementale. *Université Catholique de Louvain. 2010 ; 181*.

19 Litucha M. Effet de récolte des feuilles et du niveau d'infection secondaire de la culture par la Mosaïque Africaine de manioc sur la production de manioc (Cultivar Mbongo) dans les conditions agro-écologiques de Kisangani (R.D. Congo). Thèse de doctorat, *Institut Facultaire des Sciences Agronomiques de Yangambi. 2011 ; 325*.

20 IPAGRI, 2015. Rapport annuel de District de Mobayi-Mbongo, Province du Nord Ubangi, République Démocratique du Congo.

21 Cours G. Le manioc à Madagascar. Mémoire de l'Institut Scientifique de Madagascar, *série B, Biologie Végétale 3, 1951: 203-416*.

22 Spiegel MR. Probabilités et statistique. Cours et problèmes, *McGraw-Hill, 28 rue Beaunier, Paris. 1992 ; 381*.

23 Van Den Abeele M, Vandenput R. Les principales cultures du Congo Belge. 4ème édition, Bruxelles. 1956 ; 880.

24 Vandenput R. Les principales cultures en Afrique centrale. *Tarnai : Lessafre, Bruxelles, 1981 ; 1257*.

25 Janssens M. Le manioc *in* RAEMAEKERS Agriculture en Afrique Tropicale, *Bruxelles, Belgique, 2001 ; 194-218*.

26 Apppert J., Deuse J. Les Ravageurs des cultures vivrières et maraichères sous les tropiques. Edition GP. *Mainsonneuvre & Larose, 15 rue Victor-Cousin Paris (Vè) Agence de coopération culturelle et technique 13, Quai André Citroën Paris (XVè) France, 1982 ; 97-98.*

27 Mogo A, Temgoua E, Djeugap J, Fotso F, Fomekong J, Ngonkeu EL, Ghogomu R, Woin N, Yemefack M, Tene T. Evaluation de quelques cultivars de manioc (*Manihot*

esculenta Crantz) en fonction des populations de mouches blanches (*Bemisia tabaci* Genn), des maladies et de la fertilisation du sol [Field agronomic evaluation of some cassava cultivars (*Manihot esculenta* Crantz) against whiteflies (*Bemisia tabaci* Genn), diseases African Cassava Mosaic disease in tropical humid forest ecology of Cameroon]. *International Journal of Innovation and Applied Studies ISSN 2028-9324 Vol. 26 No. 4 Jul. 2019, pp. 1329-1345 © 2019 Innovative Space of Scientific Research Journals http://www.ijias.issr-journals.org/.*

28 Lutaladio NB, Ezuma HC. Récolte des feuilles de manioc au Zaïre In Plantes-racines tropicales : Stratégies de recherches pour les années 1980, *IITA IBADAN, Nigeria ; 42-144.*

29 N'zue B, Zouhouri PG, Sangare A. Performances agronomiques de quelques variétés de manioc (*Manihot esculenta* Crantz) dans trois zones agroécologiques de la Côte d'Ivoire. *Agronomie Africaine 2004, 16 (2) : 1-7.*

30 Fauquet C, Fargette D, Thouvenel, JC. Impact de la mosaïque africaine du manioc sur la croissance et le rendement du manioc. Phytovirologie, *ORSTOM, BP V 5 1, Abidjan, Côte d'Ivoire. 1988 ; 19-22*.