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Research Paper

A cassava mosaic disease epidemiologic factors analysis in the Bas-Congo (DR Congo) zone of savannah. case study: "Secteur de Boko"

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Abstract

This paper aims at evaluating epidemiologic parameters of the African Cassava Viral Mosaic Disease (CMVD) in 25 cassava farmer's fields of «Secteur de Boko» (DR Congo) on the basis of foliar symptoms observation. The results showed that the infection of the local varieties comes mainly from the cuttings whereas that of the improved varieties comes from the flies. The disease incidence varied between 10% and 88.33% with an average of 43.8%. Severity varied between 2.42 and 3.42 with an average of 2.913. The gravity varied between 17.86% and 87.81% while the systemicity varied between 21.42 and 96.66%. The mean number of whiteflies (*Bemisia tabaci*) by plant (2.068) revealed a preference of the vectors for the improved variety Kindombe which, however, presents a low severity and a less marked gravity. Globally, the CMVD was more severe for the local variety Mpeko with a score of 3.00. A high correlation was found between the gravity and the number of neighbour fields (-0,437*), the density of culture (-0,431*) and also the systemicity of the disease (0,779**). In addition; it appeared that the land topography strongly influences the disease severity (-0,542**).

Keywords: *CMVD; Gravity; Incidence; Severity; Systemicity.*

1. Introduction

African cassava mosaic viral disease is the major cause of cassava yield loss in Africa (Fargette et al. 1985; Hahn, 1985; Saelim et al. 2006, Ambang et al. 2007). Its ecology is singular. The disease results from the meeting of a preexistent pathogenic agent in Africa, the African Cassava Mosaic Virus (ACMV), of a host, the cassava (*Manihot esculenta* Crantz) coming from South America and introduced in Africa by a vector, an aleurode *Bemisia tabaci* Gennadius, probably originating from the Indies. It is transmitted by two modes: vegetative way during the plantation of diseased cuttings and by air through aleurode puncture. In Africa, CMVD (Cassava Mosaic Viral Disease) affects the totality of cultivated surfaces (Fargette et al. 1985).

With an annual total production estimated at nearly 15,565,000 tons (FAOSTAT 2010), the DR Congo comes, after Nigeria, in second position in the production of the roots and the tubers (mainly the cassava) on the African level. In spite of that, very few studies were relatively devoted in our country to evaluate CMVD incidence and severity, principal cause of yield loss of cassava.

However, some cases of studies in this field were carried out, although on a fewer broad surface of land. On this subject, we can note the study of Muengula-Manyi et al. (2012), based on the evaluation of the incidence, the severity and the gravity of the CMVD in Gandajika (Kasaï Oriental - DR. Congo), that of Bakelana et al. (2012) which was based on the study of the factors determining the abundance of the whitefly (*Bemisia tabaci*) as well as the epidemiologic factors of the CMVD and the Brown Streak Disease in four INERA Research Centres in Bas-Congo and Kasaï Occidental provinces.

The list of the publications on this domain in other sub-Saharan Africa's areas is, however, long. We will quote, as an indication, several studies carried out in Center and West Africa by Fargette (1987), Fauquet & Fargette (1990), Fargette and Thresh (1994), Yaninek et al. (1994), Wydra & Msikita (1998), Okao-Okuja et al. (2004), Ntawuruhunga et al. (2007) or in Southern and Eastern Africa by Bock (1988), Ogbe et al. (1996), Otim-Nape et al. (1993, 2001), Mwimba-Kankolongo et al. (1999), Legg et al. (1999), Legg (2000), Sserubombwe et al.(2001), Mallowa et al. (2006), The data discontinuity on CMVD epidemiologic parameters in the various agro-ecological areas of the DR Congo brings a major difficulty in the actualization of knowledge to the measures of effective control of the disease and put us in front of incapacity to be able to discuss effectively about this pandemia state place in our country. Therefore, it becomes necessary to constitute reliable data bases on the level of the geographical entities of realistic size to the measure of few means which we can lay out.

The present study, thus, aims to evaluate some CMVD epidemiologic parameters in "Secteur de Boko", an administrative entity of the DR-Congo, where coexist several improved varieties (because of its situation compared to the Research Centre of INERA M'vuazi) and ten others local cultivars sensitive to the CMVD. It constitutes the first study to date being interested in the evaluation of the incidence, severity, gravity of the CMVD and the number of whiteflies in Bas-Congo Province in nonexperimental conditions.

2. Materials and methods

2.1. Site of study and techniques of sampling

This investigation had been carried out in 25 agricultural farmers'fields of 13 villages randomly chosen into the four principal road axes of "«Secteur de Boko»" (RN1, RN12, RS116, RS117 and Route de Zongo) in accordance with the technique suggested by Wydra and Msikita (1998) and also advised by Sseruwagi et al (2004).

The administrative entity «Secteur de Boko» belongs to Mbanza-Ngungu Territory in Bas-Congo Province (South-western DR-Congo).

The agricultural zone belongs to AW_4 climatic type according to Köppen with a bimodal rainy season (April and November/December) and four months of a dry season. The observations were made during the rainy months from December 2012 to March 2013.

The cassava fields observed had an age from 2 to 6 MAP (Month After Plantation). The advantage of targeting plants of such age lies in the fact that at this stage, it is still possible to make the distinction between a cuttings infection and a whiteflies one (Okao-Okuja et al. 2004). A privilege was especially granted to the fields in which we could also find local varieties.

2.2. Epidemiologic parameters of the CMVD

In order to collect data, we used the technique based on the visual detection of the symptoms of cassava young plants.

Only the fields with plants having an age ranging between 2 and 6 MAP had been retained for this study.

In each field, 30 plants had been selected with regular interval over the two lengths and the diagonal according to a 'Z' configuration as proposed by Otim-Nape (1993). This configuration seemed more effective to us than that in 'X' (IITA 2009) which does not take much account of the marginal plants. The epidemiologic parameter having been retained are the incidence, severity, gravity, the systemicity and the source of infection as well as the number of whiteflies per plant. All these parameters were evaluated upon the basis of foliar symptoms.

Disease incidence refers to the percentage of the plants presenting with symptoms (Muengula-Manyi et al. 2012). CMVD severity corresponds to the symptoms intensity or the level of the disease attack. It is expressed according to a 1-5 scale (Hahn et al. 1980). In this scale, the various codes indicate:

1) An apparently healthy plant, without symptoms;
2) A light mosaic without deformation neither reduction of the size nor chlorosis and covering less than 20 % of the leaf aera;
3) A mosaic without clear reduction of the size and covering less than 50% of the leaf aera with sometimes deformation of leaves;
4) A mosaic covering the major part of the leave, accompanied by deformations and a reduction of surface;
5) Very severe mosaic symptoms on all leaves, distortion, twisting, mis-shapen and severe leaf reductions of most leaves accompanied by severe stunting of plants.

Mean severity is calculated on the basis of plants only with symptoms, making abstraction with all the healthy others (Sseruwagi et al. 2003; 2004). Gravity of CMVD per plant was assessed by the percentage of leaves with symptoms (Muengula-Manyi et al. 2012) while the systemicity refers to the proportion of shoots per plant expressing disease symptoms.

The source of infection was given according to the technique used by Okao-Okuja et al. (2004), also recommended by IITA (2009). By observing a young plant presenting symptoms and whose age is lower than 6 months, when the past formed leaves present symptoms, the infection comes from the cuttings. When only the youngest leaves present symptoms; the infection is regarded as resulting from the puncture of the whiteflies. After 6 MAP, it is difficult to succeed in making this distinction because of the senescence and the abscission of the old leaves (Fauquet & Fargette 1990).

The number of whiteflies per plant was counted on the five young final leaves (IITA 2009). The leave was delicately held by the petiole between the inch and the index, and then gently inverted so that the adults present on the lower surface can be counted (Fargette et al. 1985; Sseruwagi et al. 2003; Bakelana et al. 2012). Countings were early carried out in the morning between 6.00 and 10.00 A.M. or in the evening between 4.00 and 6.00 P.M. when the whiteflies are less active.

2.3. Measured agro-ecological parameters

Geographical coordinates of each field were recorded using a Global Position System (GPS: GARMIN *eTrex* 10). Some agro-ecological parameters were also measured. They included density of plantation, field surface, number of close fields, the age of the plants, crops mixture, land topography, intercropping practice, the presence of weed crops in the field, the source of the cuttings, the type of exploitation (familial or commercial).

2.4. Data analysis techniques

Data for the CMVD incidence were subjected to arcsinus transformation (y=arcsin $\sqrt{x}$) (Gomez and Gomez 1984) while those relating to whiteflies population were log transformed as log(x+1) (Bakelana et al. 2012; Rwegasira and Rey 2012) in order to obtain a normal distribution. After having carried out a variance homogeneity test, it did not appear necessary to proceed to the transformation of severity data.

Analysis Of Variance (ANOVA) was performed to determine responses of test cultivars to CMVD incidence, severity, gravity and systemicity of the disease with a Completely Randomized Treatment (CRT) design. The mean values of observations were separated using Duncan's multiple range tests at 0.05 level. Correlation test was done to determine the relationship among the measurable disease components. Several analyses were performed using SPSS Statistics 17.0 for Windows software. The comparison of the studied parameters between the local varieties and the improved varieties had been carried out using the T-Student test at 0.05 levels. The projection of surveyed sites on the map of «Secteur de Boko» was carried out using the ArcGIS 9.3 software.

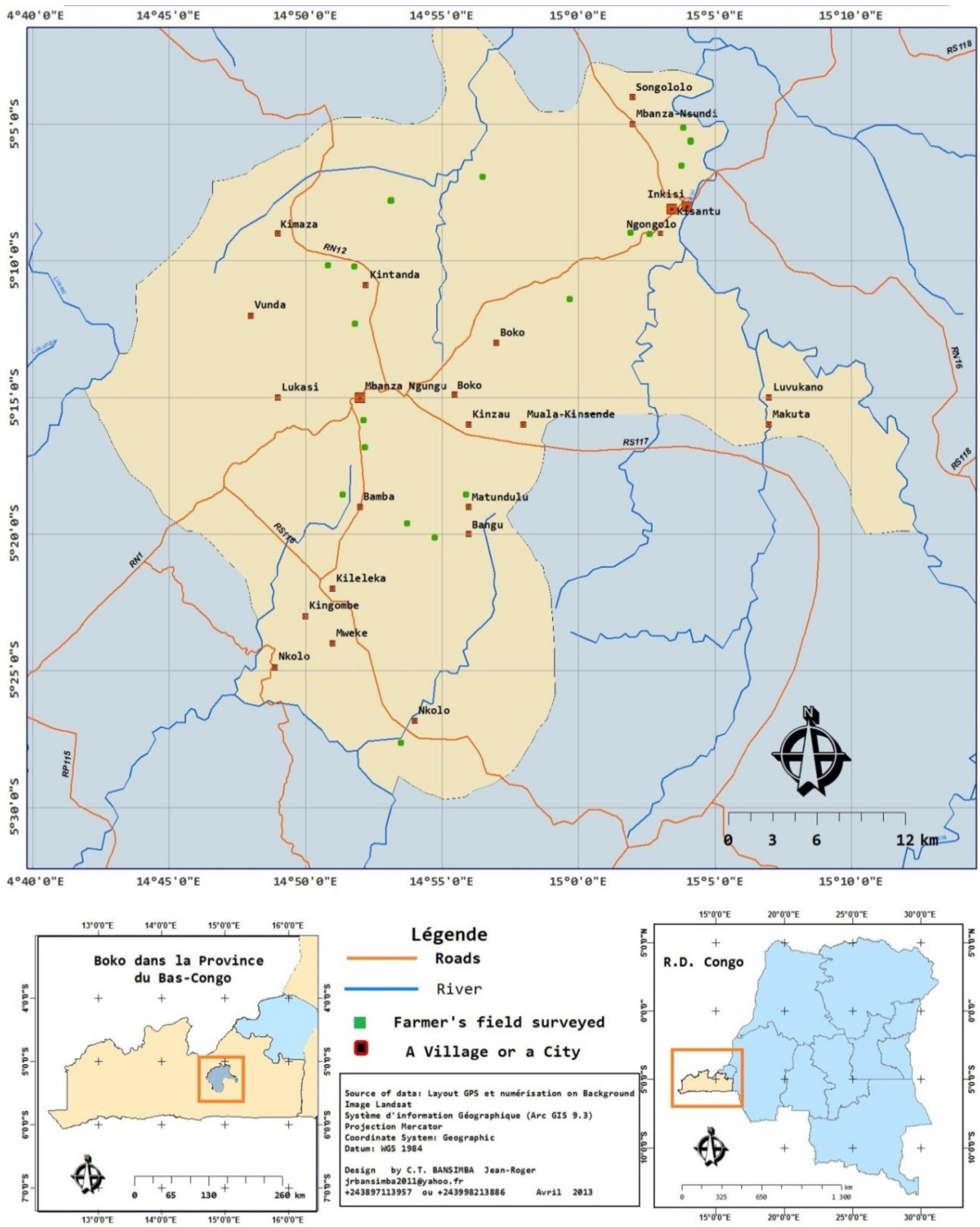

Fig. 1: Localization of the Farmer's Fields as Sampled in «Secteur De Boko»

3. Results

3.1. CMVD distribution in surveyed sites

Table 1: Relation between the Variety Type of Cultivated Cassava and the CMVD Source of Infection in «Secteur de Boko» (2012-2013).

	Source of infection		
Cultivar	Whiteflies	Cuttings	**Total**
Improved	67	147	**214**
Local	20	84	**104**
Total	**87**	**231**	**318**

Source: on the basis of data fields, 2013.

The dependence is significant $\chi^2 = 5.137^*$ (DF=1); 1-p $\geq$ 95%.

Khi-square independence test reveals a connection between the type of cultivated variety and the source of infection (Table 1). Indeed, it is noticed that the infection of the local varieties comes especially from the cuttings whereas in the majority of the cases, those of the improved varieties come from the flies.

The distribution of the infection parameters between several villages of «Secteur de Boko» is included in Table 2. The rate of infection by the flies varied between 14.3% (in Kiazi-Kolo village) and 80% (in Ngongolo) while that coming from cuttings varied between 20% (in Ngongolo) and 86% (Kiazi-kolo). The incidence of the CMVD varied between 10% and 88.33% in the village of Kiwembo where we found a woman farmer who exclusively practises the culture of local varieties.

The disease proved relatively more severe in Nkamba village with an average coast of 3.4 follow-up of Lovo (3.36), Nzundu and Pazza (3.18), then of Nsumba (3.09). It was moderate in Kimiala (2.94), Loma dia Tungua (2.9), Nkanda (2.68), Kiwembo (2.57), Ngongolo (2.55), Mbamba (2.51), and finally in Kiazi-kolo (2.42). The average number of flies *Bemisia tabaci* per shoot of cassava varied between 0.522 (in Kiwembo) and 3.60 (in Nkamba).

The severity, gravity and systemicity Analysis Of Variance (ANOVA) was carried out in order to compare these parameters according to the various varieties cultivated by the farmers (Table 3).The results revealed that the disease was at significant degree ($p<0.05$) more severe for the local variety Mpeko (3.00) and for Sadisa (2.97), improved variety (Figure 2). With regard to gravity, it is necessary also to notice a greater proportion at the local varieties Kuseko (87.81%), Mpeko (76.8%), Kimaza-maza (65.9%), followed directly by the improved variety Sadisa (55.1%).

The systemicity data analysis revealed the existence of a first group, including Kuseko, Mpeko, Kimaza-maza and Sadisa, a second group, including Bulumuna, Nsumbakani, Kisensekele, Mapuata and Kizeladi, a third formed group of Kiteba alone and finally a fourth group, including Papayi, Kindombe and RAV at which the disease is the least systemic.

The mean number of whiteflies *B. tabaci* by plant according to the varieties revealed a preference of the vectors for the improved variety Kindombe (Ngai-ngai) which, however, presents a low severity and a less marked gravity. Among all, Kuseko local variety is preferred by whiteflies. It is released some clearly that whiteflies prefer to nourish themselves on the healthy plants rather than on already sick shoots. As a whole, it released a significant difference between local cultivars and improved ones with regard to severity, gravity, systemicity and even with regard to the mean number of whiteflies (*B. tabaci*) per plant (Table 4).

(1)

(2)

Fig. 2: Several Attack Levels of Cassava Shoots by the Mosaic: 1) A Local Variety (Mpeko) Presenting A Severity Score of 3. 2) An Improved Variety (Sadisa) with a Severity Score of 5.

Concerning the distribution of the local varieties in «Secteur de Boko», it was clearly noticed an increase in the frequency of appearance as we move away from M'vuazi which is a point of diffusion of the improved varieties. Indeed, INERA Research Centre highly recommends to the peasants the systematic abandonment of local varieties so that it was very difficult to find them in the immediate surroundings of M'vuazi.

In overall, it was not possible to highlight a gradient of incidence neither of severity nor even of the other epidemiologic parameters of the CMVD in the Sector of Boko, which it acts around the INERA/M'vuazi Research Centre or on the five principal road axes (RN1, RN12, RS116, RS117 and Route de Zongo) on which were localized our sites of study.

3.2. Agro-environmental parameters

Land Topography:

In the majority of the cases (72%), the peasants cultivate cassava in flat ground. However, in the various areas of Mbamba village (alt. 715 - 785 m), located in the neighborhood of Mbanza-Ngungu where the ground is inclined, the flat sites of the valleys are reserved for market gardening, the peasants dominant activity. The culture of cassava, ancillary activity, remains relegated to the inappropriate grounds of the slopes.

Table 2: Incidence, Severity and Whitefly Bemisia Tabaci Abundance in the Villages of «Secteur de Boko».

Parameters	Villages												
	Nsumba	Ngongolo	Kimiala	Lovo	Pazza	Nzundu	Loma	Mbamba	Kiazi-Kolo	Nkanda	Nkamba	Kiwembo	**Mean**
Nb fields	1	2	5	1	1	1	1	5	1	2	2	3	**2.083**
Inf.flies(%)	60	80	22	76	55	67	40	18	14	15	42	17	**42.167**
Inf.cutt.(%)	40	20	78	24	45	33	60	82	86	85	58	83	**57.833**
Incidence	46.7	14.98	41.46	46.67	36.67	10.00	33.33	50.67	23.33	63.33	70	88,33	**43.789**
Severity	3.09	2.55	2.94	3.36	3.18	3.33	2.9	2.51	2.42	2.68	3.42	2.577	**2.913**
# *B. tabaci**	3.467	3.216	1.433	1.767	2.867	0.533	1.367	1.36	3.233	1.45	3.60	0.522	**2.068**

Source: Computed on the basis of data fields, 2012-2013.

Abbreviations in the table: 'Inf.flies' for Percentage of flies infection and 'Inf.cutt.' for Percentage of cuttings infection. 'Nb fields' pour Number of surrounding fields. * Untransformed data.

Table 3: Incidence, Severity and Whiteflies *Bemisia tabaci* Abundance according to Cultivated Varieties (Duncan's Multi Range Test at 0.01 level). The Data of Whiteflies Abundance were transformed x'=log(x+1).

Varieties	Severity	Gravity	Systemicity	Nb.flies
Improved				
Papayi	1.29a	17.86a	21.42a	0.397bcd
Kindombe(Ngai-ngai)	1.33a	17.95a	33.33a	0.41d
RAV	1.52a	18.54a	21.41a	0.323abc
Sadisa	2.97d	55.11bc	74.75bcd	0.538cd
Nsumbakani	1.82abc	37.16ab	46.93abc	0.347abc
Bulumuna	1.92abc	44.60ab	55.90abc	0.210ab
Kiteba	1.88abc	37.98b	40.98ab	0.271ab
Local				
Kisensekele	1.91abc	32.63ab	45.45abc	0.333abc
Mapuata	1.74abc	41.66ab	47.62abc	0.207ab
Kizeladi	1.95abc	34.37ab	43.90abc	0.403bcd
Mpeko	3.00d	76.84cd	80.00cd	0.311abc
Kimaza-maza	2.37bcd	65.96bcd	77.22bcd	0.107a
Kuseko	2.43cd	87.81d	96.66d	0.088a
F	8.204	12.424	13.978	5.983
DF	671	671	671	671
1-p ≥ 99%	**	**	**	**

Source: Computed on the basis of data fields, 2012-2013.
N.B. Values followed by different letters in a column were significantly different as determined by Duncan's Multiple Range Test (1-p ≥ 99%); ** highly significant (p<0.01). Abbreviation in the table: 'Nb.flies' for Number of flies; 'DF' for Degree of Freedom.

Table 4: Values of the Severity, the Gravity and the Systemicity as well as those of *B. tabaci* Population for the two Types of Varieties (T-Student Test at 0.05 Level).

	Epidemiological parameters			
Cultivar (N)	Severity	Gravity	Systemicity	*B. tabaci* population [a]
Improved (513)	1.74	29.29	35.72	1.88
Local (159)	2.04	53.55	62.37	1.01
t (1-p ≥ 95%)	-3.65*	-6.56*	-6.42*	3.82*
DF		670		

*: Significant (p<0.05) [a]: Non-transformed data; 'DF': Degree of Freedom.

Type of exploitation:
The various exploitations are familial type as well as commercial type in 2012-2013. In all the cases, cultivated surfaces remain relatively less significant. At all events, the products of harvest are intended for subsistence farming as well as for sale.
Source of cuttings:
Cuttings come especially from the self-production (52%), then from the purchase (32%). Only 12% of farmers affirmed to be accompanied by NGOs and associations and only 4% are supplied directly by INERA M'vuazi Research Centre.
Crops Rotation Practice:
It was rare to find in "Secteur de Boko" peasants who practice the crops rotation as systematic way (12%). In the majority of the cases, they re-plant cassava on the same ground after harvest, sometimes several times of continuation until the ground exhaustion.
Association of the Cultures and Topping Practice:
For nearly 56% of the cases, the farmers practise monoculture. Only 44% of the fields were counted among those where the cassava is associated with other cultures such as groundnut, sweet potato, niébé or beans. The practice of topping was found only in 36% of the sites. Indeed, cassava leaves are generally collected only starting from 6 MAP.
Presence of weeds:
Weeds are present in fields in 64% of the cases. The sites in which weeds were found are Ngongolo (100%), Kimiala (60%), Loma (100%), Mbamba (80%), Nkanda (100%), Nkamba (100%) and Kiwembo (66%). On the other hand, one found fields weeded in the sites of Nsumba (100%), Kimiala (40%), Lovo (100%), Pazza (100%), Mbamba (20%) and Kiazi-Kolo (100%). In the large majority of the cases, the farmers let the fields grow with their weeds, especially if each household has some several or if the extents to be managed are significant. Around 12 MAP, for the improved varieties, the farmers decide to uproot completely cassava crops still mixed with weeds.

3.3. Correlations between variables of study

Table 6 shows the correlations between various studied variables. It reveals a significant connection between the number of neighbour fields and the density of plantation (0.425*). The incidence of the CMVD is also related to the systemicity (0.543**) and the gravity (0.717**). This one is, moreover, related to the number of neighbour fields (-0.437*), to the density of culture (-0,431*) and to the disease systemicity (0.779**). However, no connection appeared between the presence of weeds and all the other studied parameters. Moreover, the analysis of these results shows that the land topography strongly influences the disease severity (-0.542**).
The correlation between epidemiologic parameters can be visualized in the diagram of Figure 3 resulting from the Principal Components Analysis (PCA) of the studied system epidemiologic parameters. Each principal axis or component explains a value of the considerable original variance (45.2% of variance for axis 1; 67.3% of total variance explained by the sum of the first two axes). Thus, visualized dispersion roughly accounts for 67.3% (Component 1 and Component 2) of the variation of the studied system. It is, thus, dissociated very clearly that the incidence, gravity; the systemicity of the disease are very dependent; the average number of flies per plant is, on the other hand, conversely correlated with the incidence, the gravity and the systemicity of the disease. This situation is also found between the severity and the density of plantation or the number of neighbour fields.

Table 5: Relative Frequency (%) of the Principal Agro-Ecological Characteristics of the Farmer's Exploitations in the Various «Secteur de Boko» Sites of Study (DR. Congo).

	Sites												
	Nsumba	Ngongolo	Kimiala	Lovo	Pazza	Nzundu	Loma d.T.	Mbamba	Kiazi-Kolo	Nkanda	Nkamba	Kiwembo	**Percentage**
Type of exploitation													
Familial	100.0	50.0	20.0	0.0	100.0	100.0	100.0	40.0	100.0	0.0	0.0	100.0	**48.0**
Commercial	0.0	50.0	80.0	100.0	0.0	0.0	0.0	40.0	0.0	100.0	100.0	0.0	**48.0**
Schoolar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	**4.0**
Source of cuttings													
Selfproduction	0.0	0.0	80.0	0.0	0.0	0.0	0.0	40.0	0.0	100.0	100.0	100.0	**52.0**
Purchasing	100.0	100.0	20.0	100.0	0.0	0.0	0.0	40.0	100.0	0.0	0.0	0.0	**32.0**
NGOs and associations	0.0	0.0	0.0	0.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	**12.0**
INERA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	**4.0**
Land topography													
Plate	100.0	50.0	80.0	100.0	100.0	100.0	100.0	0,0	100.0	100.0	100.0	100.0	**72.0**
Slope	0.0	50.0	20.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	**28.0**
Crop Rotation													
Yes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	100.0	0.0	**12.0**
No	100.0	100.0	100.0	100.0	100.0	100.0	100.0	80,0	100.0	100.0	0.0	100.0	**88.0**
Crops mixed with cassava													
Yes	0.0	50.0	20.0	0.0	100.0	100.0	100.0	100.0	100.0	50.0	100.0	0.0	**56.0**
No	100.0	50.0	80.0	100.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	100.0	**44.0**
Presence of weeds													
Yes	0.0	100.0	60.0	0.0	0.0	0.0	100.0	80.0	0.0	100.0	100.0	66.7	**64.0**
No	100.0	0.0	40.0	100.0	100.0	100.0	0.0	20.0	100.0	0.0	0.0	33.3	**36.0**
Topping practice													
Yes	0.0	0.0	20.0	100.0	0.0	0.0	0.0	60.0	100.0	100.0	0.0	33.3	**36.0**
No	100.0	100.0	80.0	0.0	100.0	100.0	100.0	40.0	0.0	0.0	100.0	66.7	**64.0**

Source: Computed on the basis of data fields, 2012-2013.

Table 6: Bilateral Correlations between CMVD Epidemiological Variables and Some Agricultural Parameters in Farmer's Field.

	Neigh. fields	Dens.m^2	Nb.flies	Incidence	Severity	System.	Gravity	Weeds	Topogr.
Neigh.fields	1,00								
Dens.m^2	0,425*	1,00							
Nb.flies	-0,122NS	-0,212NS	1,00						
Incidence	-0,133NS	-0,128NS	-0,360NS	1,00					
Severity	-0,352NS	-0,293NS	0,057NS	0,281NS	1,00				
Systém.	-0,291NS	-0,313NS	-0,278NS	0,543**	0,593**	1,00			
Gravity	-0,437*	-0,431*	-0,329NS	0,717**	0,389NS	0,779**	1,00		
Weeds	-0,110NS	0,025NS	0,148NS	-0,311NS	0,227NS	0,133NS	0,054NS	1,00	
Topogr.	0,005NS	0,070NS	-0,054NS	-0,210NS	-0,542**	-0,330NS	-0,172NS	-0,282NS	1,00

*significant ($p<0.05$) ; ** highly significant ($p<0.01$) ; NS : non-significant ; Abreviations in the table: 'Neigh.fields.' for number of neighbour fields, 'Dens.m^2' for Crops density in m^2, 'Nb.flies' for Mean number of whiteflies per shoot, 'Systém.' for Systemicity and 'Topogr.' for Land Topography.

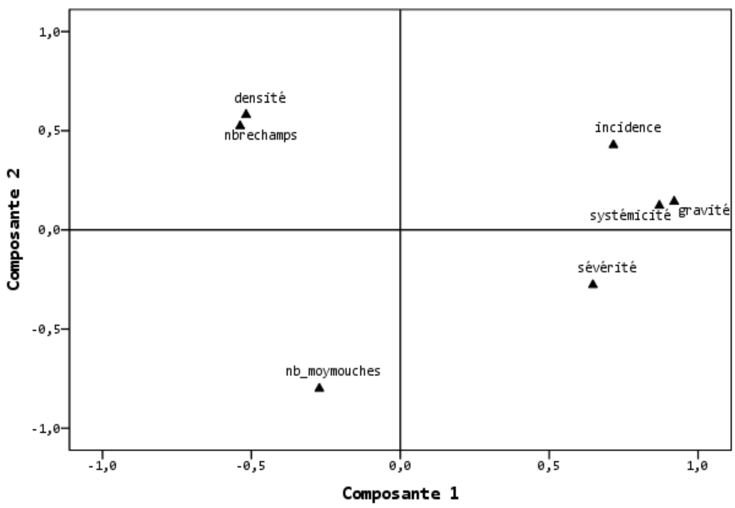

Fig. 3: Principal Components Analysis (PCA) Showing the Correlation between Several Epidemiologic Variables. Abbreviations in the Figure: 'Nbrechamps' For Number of Fields; 'Nb_Moymouches' For Mean Number of Whiteflies per Shoot.

4. Discussion

4.1. Epidemiologic parameters

This study represents the first epidemiologic investigation of the CMVD in farmer's fields in the Province of Bas-Congo. It has the merit to provide reliable informations for the constitution of a data base relating to this pandemia in the south-western part of Democratic Republic of the Congo.

The results recorded on ground show us that the infection of the local cultivars comes especially from the cuttings whereas those of the improved cultivars come from the flies. These facts are almost similar to those reported by Okao-Okuja (2004) in Senegal.

The CMVD severity was moderate through the various sites of study with an average of 2.91 in «Secteur de Boko» similar to 2.8 found in the Territory of Gandajika (Muengula-Manyi et al. 2012) or between 2.6 and 2.7 in the District of Siaya in the west of Kenya (Mallowa et al. 2006).

Contrary to Soyode and Oyetunji (2009) in Nigeria and to Rwegasira et al. (2012) in Tanzania who reported a highly significant correlation between the incidence of the CMVD and severity, our study did reveal a highly significant correlation ($P \geq 0.001$) only between the incidence and gravity and with the systemicity. That could be quite simply due to a difference in more or less subjective appreciation of the severity scale.

The analysis of the variance showed a significant difference between the various varieties with regard to the epidemiologic factors studied as noted by Rwegasira et al. (2012) in Tanzania. Globally, the disease was more severe on the local cultivars than on those which are improved. Nevertheless, this situation is not immutable in time and can even suffer besides from many exceptions. Indeed, the example of the Sadisa variety can be evoked as an indication: this improved variety was very resistant when it was, firstly, introduced into the region in 1995 (Anonyme 2008). That is why it was called by the peasants "RDC-Eloko ya Makasi," which means "DRC-very strong material." Nowadays, Sadisa variety is among those at which CMVD are not only most severe but also most serious and the most systemic (see Table 3).

However, no correlation could be established between the population of the whiteflies (*Bemisia tabaci*) and the epidemiologic factors evaluated. This fact had already been noticed by Fargette et al. (1985), by Muengula-Manyi et al. (2012) as well as by Bakelana et al. (2012), contrary to Rwegasira et al. (2012) which noted a significant influence of the population of the whiteflies on the incidence and the severity of the CMVD. In all the cases, system Cassava-Mosaic-Flies is very complex and its analysis requires the simultaneous taking into account of various parameters, amongst other things as the climatic factors (Fargette and Thresh 1994), the type of plant, the proportion of the vectors and the vectors activity and flight (Bakelana et al. 2012).

The number of white flies was less on the diseased plants and higher on the healthy plants or fewer diseased ones. This result confirms the former report made by several authors (Fauquet et al. 1985; Otim-Nape 1993; Sserubombwe et al. 2001) showing that the white flies prefer to nourish themselves on fewer diseased plants rather than on those which contain more viruses.

4.2. Agro-environmental factors

The cassava is cultivated more on flat grounds than on slopes. In all the cases, if the ground topography is not dependent with the incidence of the CMVD (R = 0.210NS), it was noticed that severity was much more significant on flat grounds than on the slopes.

The cuttings used are mainly produced by the farmers themselves. The absence of control measurements of their quality implicates, like noticed it Bock (1988), maintenance of a permanent infectious state, even a recrudescence of the disease on certain varieties.

The rotation of crops is practiced only by a minority of peasants. Generally, the peasants re-plant the same culture continually until the ground exhaustion. A similar situation was noticed in Gandajika (Muengula-Manyi et al. 2012). However, no ratio could be established between the crops rotation and the incidence or the severity of the CMVD; this report was also made in connection with the practice of the association of the cultures as underlined by Thresh and Cooter (2005).The presence of weeds in the majority of the fields on which the study was undertaken appeared not to have a direct influence on the epidemiologic parameters of the CMVD.

The density of plantation exerts also an influence on the epidemiologic parameters of the CMVD. It appears very significant that the fields where the density is high present a weak CMVD gravity. Although no significant, this negative correlation also exists between the density and the incidence, the severity or the systemicity. According to Fargette et al. (1985) which also highlighted a speed of slower contamination in the fields where the density was higher, it would be possible that these differences in behavior are in relation to differences over the size or the behavior of the insect vector.

5. Conclusion

This study made possible to give a report on the african Cassava Viral Mosaic Disease situation in an agro-ecological zone of savannah in the Province of Bas-Congo in the South-west of the DR Congo between December 2012 and March 2013. The work carried out showed a variation in the distribution of the disease between the various sites as well as a fluctuation of the epidemiologic parameters between the various varieties. The infection of the local varieties comes especially from the cuttings whereas that of the improved varieties is, in the large majority of the cases, the work of the flies.

The rate of infection by the flies oscillates between 14.3% and 80% while that charged to the cuttings was between 20% and 86%. Between the several villages, the incidence of the CMVD varied between 10% and 88.33%. The average number of flies (*Bemisia tabaci*) per cassava shoot varied between 0.522 and 3.60 and, compared to the varieties, it proved to be a preference of the vectors for the healthy shoots rather than on the diseased ones. The incidence, severity, gravity and the systemicity were more significant on the local varieties than on the improved varieties.

Among the agro-environmental factors studied, only the land topography had a remarkable influence on CMVD severity as well as the density of plantation, which strongly had an impact on the gravity of the disease. On the other hand, the crop rotation practice, the association of the cultures and the topping practice as well as the presence of weeds did not have any influence on the epidemiologic parameters of the disease.

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