Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 11 ~ Issue 5 (2024) pp: 01-08
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

Epidemic characteristics and cultivars field resistant to cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) in former Oriental Province in the Democratic Republic of Congo

EMPATA Lydie[1,2*], BULONZA Jean-Claude[1,2], EBWA Joel[1,2], NZAWELE Dowiya Benjamin[1,3]et MONDE Godefroid[1,2]

1. *Faculty Institute of Agronomic Sciences of Yangambi (IFA-Yangambi) P.O. Box 1232 Kisangani,*
2. *WAVE-IFA Yangambi, Phytopathology and Plant biotechnology laboratory, P.O. Box 1232 Kisangani .*
3. *IFA-Yangambi, Genetic and crop breeding laboratory (LGAP), B.P. 28 Yangambi, 1232. Kisangani*

**Corresponding author*

In DRCongo, cassava cultivation deserves special attention due to threat of emerging and devastating viral diseases. The study consisted to determinethe epidemic level and to identify some cassava cultivars field resistant to cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) in ex-Province Oriental in the DR Congo. An epidemiological surveywas carried out in the provinces of Tshopo, Bas-Uele, Haut-Uele and Ituri in February 2022. A total of 180 cassava fields from5 to 9 months old after planting were surveyed.The results showed an average incidence of CMD of 68.88% with a severity level of 2. A moderate incidence of CBSD observed with an average of 17.54% and a severity of level 2. This reflects the progression of the disease from eastern neighboring countries into areas not yet infected byCBSD in DRCongo. The highest whitefly densities were found in the provinces of Tshopo and Ituri with 5 whiteflies/plant. While, in the provinces of Bas-Ueleand Haut-Uele a lower whitefly density with 1 whitefly/plantwas observed. A number of cultivars resistant to CMD and CBSD determined in the field may contribute for addressing these viral pandemics.

Keywords: *CMD, CBSD, incidence, severity, whitefly, fieldresistance*

***R**eceived 04 May, 2024; **R**evised 13 May, 2024; **A**ccepted 16 May, 2024 © The author(s) 2024.*
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I. INTRODUCTION

Cassava is a staple food crop in the Democratic Republic of Congo (DRCongo). Its importance is attested not only by the extensionof the area under cultivation, but also by the diversity of its uses in both human and animal nutrition. Cassava is a major production with leaves and tubers available all times of the year. Cassava leaves, mainly used in DR Congo as vegetables, are a richer source of protein (Mahungu *et al*., 2014).

Increasing cassava productivity in DRCongo unfortunately encounter several biotic and abiotic constraints that induce a decline it productivity. These include Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD), both transmitted by infected cuttings and bywhitefly *Bemisia tabaci* Gennadius (Hemiptera Aleyrodidae). They are harmful viruses (Maruthi *et al.*, 2005; Mulimbi *et al*., 2012; Monde *et al.*, 2013, Bisimwa *et al.,* 2015). CMD and CSBD, two viral diseases, can reduce cassava yields by 100% (Legg *et al*., 2011; Njoroge *et al.*, 2017) and pose a real threat to people's food security (Alicai *et al.*,2007; Winter *et al.*, 2010; Bigirimana *et al*., 2011).

Symptoms of cassava mosaic diseasearecharacterized by alternating green and light-green or yellow patches on the leaves, depending on the variety of cassava, the strain of virus and environmental conditions. In the advanced stages of cassava mosaic disease, leaves often become twisted and show a significant reduction in area. When the disease is severe, plants remain dwarfed and stunted (Maruthi *et al*., 2004; Bull *et al*., 2006). The same symptoms were found in Central Africa (Zinga *et al*., 2012; Bisimwa *et al*., 2012; Monde *et al.,* 2013; Mouketou *et al.,* 2020; Doungous *et al.*, 2022) and West Africa (Pita *et al.*, 2001; Tiendrébéogo *et al.,* 2012, Soro *et al*., 2021).

Most of the studies carried out in DR Congo have been in the eastern part of the country and sometimes in the south and south-west of DR Congo, leaving the western part of the country unexplored(Bisimwa *et al.*, 2012 ; Monde *et al*., 2010 ; Monde *et al*., 2013 ;Bisimwa *et al.*, 2015 ; Biola *et al.*, 2022).

Cassava brown streak originates from countries in the coastal zone of East Africa, where it has remained confined since the years 1935-1946 before its detection in 1936 in Tanzania, then in 1946 in Kenya, from where it spread in 2003 to Uganda, and to Rwanda and Burundi in 2009 and 2011, respectively (Legg *et al*., 2015; Mulimbi *et al*., 2012) and to DR Congo in 2019 (Casinga *et al*., 2019).

These two viral diseases represent a major threat to food security, particularly for small-scale subsistence farmers. The latter contribute through ignorance to the spread of the viruses by exchanging infected cuttings (Zinga *et al*., 2008; Muhindo *et al*., 2022; Bulonza *et al.*, 2024). The aim of this study was to provide an update on the epidemic situation of these two viral diseases (CMD and CBSD) in the former Orientale Province through epidemic surveillance.

II. MATERIALS AND METHODS

A geo-referenced survey forCMD and CBSD was conducted from February 01 to March 28, 2022 in the four Provinces of the former Orientale Province (notably Tshopo, Bas-Uele, Haut-Uele and Ituri regions).

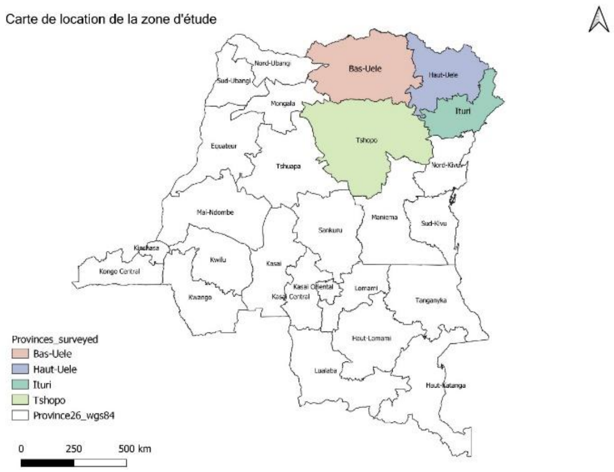

Figure 1: Geographical location of the former Orientale Province in DR Congo

During this surveillance, ten cassava fields per territory were surveyed in each province, along main roads at intervals of 10 km between fields. Diagnosis of diseases (CMD and CBSD) was carried out visually in the field.

A total of 180 cassava fields were surveyed in the former OrientaleProvince. This number was distributed as follow: 70 cassava fields in the Tshopo Province, 40 fields in Bas-Uele, 50 fields in Haut-Ueleand 20 in Ituri. In each field surveyed, 30 cassava plants were analyzed for CBSD and CMD, at a rate of 15 plants per diagonal, using the iForm application. The geographical coordinates of the surveyed fields were taken using a Garmin62 S GPS (Global Positioning System). Phytosanitary surveys in relation to cassava brown streak disease and cassava mosaic disease focused on the following epidemiological parameters:

a) Disease severity

The severity of cassavamosaic disease was assessed according to the 1 to 5 rating scale (Monde, 2010) as illustrated in figure 2.

Figure 2: Cassava mosaic disease severity scale

Level 1: No visible symptoms on leaves
Level 2: Appearance of slight chlorotic patches on leaves
Level 3: Chlorotic patches on almost all leaves without leaf surface deformation
Level 4: Chlorotic patches covering most of the leaf, accompanied by deformation, curling and reduction of leaf area.
Level 5: Severe mosaic, leaves twisted, deformed and practically reduced to the veins.

While the severity of cassava brown streak disease on theleaves and tuberous roots was assessed using rating scale as shown in Figure 3 that was developed byMuhindo et al. (2020).

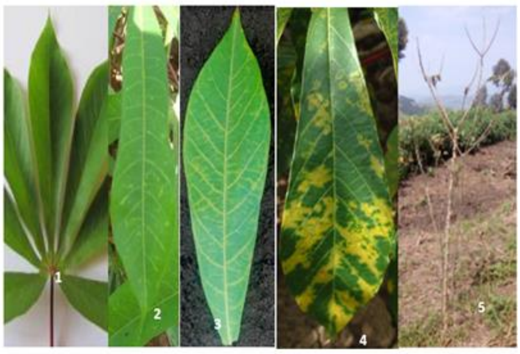

Figure 3: cassava Brown streak disease severity scale on leaves

Legend for severity scale on leaves:
- Level 1: No apparent symptoms on leaves;
- Level 2: Slight leaf symptoms, no stem lesions;
- Level 3: Leaf chlorosis, moderate lesions, no die-back;
- Level 4: Leaf chlorosis and pronounced stem lesions, no die-back;
- Level 5: Defoliation with stem lesions and pronounced die-back.

The average severity of each virus was determined by the following mathematical relationship as follows:
Average severity=(sum of individual symptom scores of diseased plants)/(number of diseased plants) (1)

b) Disease incidence in the field

Field incidence was determined by the following mathematical relationship
Incidence (%)=Number of diseased plants/Total number of plants surveyedx 100(2)

c) Whitefly abundance

To determine the abundance of the vector on cassava plants under cultivation, we counted the whiteflies present on the first 5 apical leaves in the morning before noon.

d) Source of viral infection

The source of viral infection was determined by considering the position of symptoms on the leaves. When symptoms are found on the apical leaves, infection is attributed to whitefly; when symptoms are found on the basal leaves, infection is attributed to cuttings infected before planting.

e) Field-resistant cultivars to CMD and CBSD

The incidence and severity data recorded have enabled us to identify a number of cassava cultivars with field resistance to CMD and CBSD. Cultivars of cassava that did not show symptoms of both CMD and CBSD in the field was considered field resistant to both diseases. The data collected were analyzed and descriptive statistics' used for their analysis.

III. RESULTS

1. Number of fields surveyed, average field ages,cassava cropping systems, and epidemics characteristics of CMD and CBSD in Orientale Province

Results in Table 1 show that the age of cassava crops encountered in the former Orientale Province ranged from 5 to 7 months. The age distribution by province is as follows: Tshopo province (5 months), Bas- Uele (7 months), Haut- Uele(7 months), Ituri (6 months). Based on these results, it is determined that the average age of cassava fields found in the former OrientaleProvince was 6 months. This means that our investigations has been done at the appropriate periodwhen CMD and CBSD symptoms were most visible on leaves .

The results also indicate that cassava is not in monoculture plantation in Orientale Province; cassavais generally grown in association with other food crops such as banana, sweet potato, sugar cane, maize, rice, pineapple, etc.

Table 1 : Epidemics characteristics of CMD and CBSD in Orientale Province
n: Total of cassava fields prospected by province

Provinces	District	Age (map)	Crops associated	White fly abundance	Incidence (%) CMD	Incidence (%) CBSD	Severity (1-5) CMD	Severity (1-5) CBSD	infection origins (%) Cuttings	infection origins (%) White fly
Tshopo (n=70)	Isangi	5	Banana, sugar cane	2	77.77	11.11	2	2	33.33	55.55
	Basoko	6	Maize, banana , sweet potato	3	88.80	0	2	1	55.55	44.44
	Ubundu	5	Banana	11	94.74	0	2	1	14.28	85.14
	Yahuma	5	sugar cane Banana , sweet potato	4	100	14.28	2	2	42.85	71.42
	Opala	7	Banana	4	100	25	2	2	62.50	37.50
	Bafwasende	7	Banana , maize, sweet potato	6	71.81	0	2	1	74.77	4.44
	Average	**5**		**5**	**88.85**	**8.39**	**2**	**2**	**47.21**	**49.74**
Bas- Uélé (n=40)	Buta	7	Sugar cane , Banana pineapple , oil palm	0	100	0	2	1	58.51	41.48
	Bondo	7	Sweet potato , Banana , oil palm	0	62.50	0	2	1	63	0
	Aketi	8	Bananier, pineapple , sugar cane , tomato	0	33.33	0	1	1	100	0
	Bambesa	8	Sugar cane, bean, sweet potato	4	35.90	33.90	2	2	11.11	44.44
	Average	**7**		**1**	**57.93**	**8.47**	**2**	**2**	**58.15**	**21.48**
Haut-Uélé (n=50)	Wamba	7	Sweet potato , pinaple, Banana	2	66.66	16.66	2	2	80	20
	Niangara	8	Rice, bananier , sweet potato	0	100	0	3	1	100	0
	Dungu	9	Banana, sugar cane , pineapple, rice	0	37.5	50	2	2	87.5	12.5
	Faradje	7	Rice, Banana sweet potato	2	100	0	2	1	75	25
	Rungu	6	Banana, sweet potato	5	55.55	0	2	1	44.44	0
	Average	**7**		**1**	**71.94**	**13.33**	**2**	**2**	**77.38**	**11.50**
Ituri (n=20)	Mambasa	8	Banana	3	33.60	0	2	1	36.94	0
	Aru	5	Banana	8	80	80	2	2	60	60
	Average	**6**		**5**	**56.83**	**40**	**2**	**2**	**48.47**	**30**

Cassava cropping systems

Results in Table 1 show that all the cassava fields surveyed were always in association with other food crops. This can be explained by demographic pressure, that causes difficultiesto access to the land resources. This constraint obligefarmers to practice intercropping in order to make sown areas more profitableand to diversify food. Indeed, the intercropping system makes farming more profitable, as the secondary crops associated with the main crop benefit from agronomic practices linked to land preparation and weeding.

Abundance of whiteflies

Whitefly abundance in the former Orientale Province was generally low, and the results show that their populations recorded in surveyed cassava fields were less dense. In the provinces of Tshopo and Ituri, they were 5 white flies/ cassava plant respectively. However, in the provinces of Bas-Ueleand Haut-Uele, only one white ly is recorded per cassava plant.

Incidence and severity of CMD and CBSD

Results in Table 2 show that high incidences of CMD were found in Tshopo (88.85%) and Haut-Uele(71.94%) provinces. In addition, a relatively low level of incidence was recorded in Bas-Ueleprovince (57.93%).However, the severity of CMD remained at level 2 in all provinces surveyed. Overall, the CMD pandemic is at a high level in the former OrientaleProvince.

On the other hand, our results indicate that the incidence of CBSD is relatively high in Ituri province (40%), followed by Haut-Ueleprovince (13.3%). However, a relatively low incidence was recorded in Tshopo Province (8.39%), and Bas-UeleProvince (8.47%).

However, the severity of CBSD remained at a level 2 in all provinces surveyed. Overall, the CBSD pandemic is still at a moderate level in the former OrientaleProvince.

Source of disease infection

Results in Table 1 show that the main source of CMD and CBSD infection is the use of already infected cuttings to establish a new plantation (57.80%). Whiteflies play a minor role (28.18%) in the infection of these viral pandemics.

Our investigations indicated the followingresults: Tshopo (47.21% infected cuttings vs. 49.74% infected whiteflies), Bas-Uele(58.15% infected cuttings vs. 21.48% whiteflies), Haut-Uele(77.38% infected cuttings vs. 11.50% whiteflies) and Ituri (48.47% infected cuttings vs. 30% whiteflies).

2. Cassava cultivars field-resistant to CMD and CBSD

Table 2 shows the different cassava cultivars with field resistance to CMD, CBSD and cross-resistance (CMD&CBSD).

Table 2: Cultivars resistant to CMD and CBSD in the field

Province	Number of in field- resistant cultivars to CMD	Number of in field-resistant cultivars to CBSD	Number of filed-resistant cultivars to both CMD and CBSD
Tshopo (n=57)	4 (7%)	38 (67%)	3 (5%) Mboloko, omondodi, litembele
Bas-Uele(n=44)	15 (34%)	32 (73%)	12 (27%) Ngonde,Mbongo,Angonde,Zakando,Nikazalo,Ngende,Ngazi Mambengo,Somadi, Mambele,Mbongo Obama
Haut-Uele(n=27)	12(44%)	26 (96%)	7 (26%) Inconnue, Fabo, Kelenga, Songo, Agbalakumu, FAO, Obama
Ituri (n=12)	1 (8%)	8 (67%)	0 (0%)

Results for Tshopo province show that the majority of cassava cultivars were asymptomatic to CBSD (38/57 (67%)), while fewer cultivars were asymptomatic to CMD (4/57 (7%) out of all cultivars surveyed). Regarding cross-resistance (CMD and CBSD), fewer cultivars recorded in Tshopo Province (3/57;5%) showed no symptoms of CBD or CMD.

In Bas-UeleProvince, the majority of cultivars examined showed resistance to CBSD in the field, i.e. (32/44), 15/44 cultivars resistant to CMD in the field and 12/44 cultivars with cross-resistance to both CMD and CBSD in the field.

In Haut-Uele Province, results showed that 12 /27 cultivars (or 44%) were field- resistant to CMD. While, 26/27 cassava cultivars were field-resistant to CBSD and 7/27 cultivars (or 26%) expressed cross-resistance in field.

In Ituri province, results showed that 1/12 cultivars (or 8%) showed in field resistance to CMD and 8/12 cultivars (or 67%) showed in field resistance to CBSD, while no cassava cultivar showed cross-resistance to CMD and CBSD.

Haut-Uele province leads with a high proportion of cassava cultivars (44%) showing in field resistance to CMD, and cross-resistance of 26%. While Bas-Uele followed in decreasing order with 34% of in field resistance to CMD and 27% cross-resistance.

With regard to field resistance to CBSD, the highest percentages were recorded in the provinces of Haut-Uele and Bas-Uele, with 96% and 73% respectively. Higher number of cultivars withfield resistance character to CBSD were identified, while those with resistance to CMD were few in number.

IV. DISCUSSION

Ourresults show that in the former OrientaleprovinceinDRCongo, cassava cultivation in association with other crops is the most important cropping system applied by farmers(Table 1). Associated cassava fields were dominated by banana, maize, rice, sugarcane, pineapple and sweet potato, etc. This is in line with situations in other tropic regions, where many crops were grown in association with cassava (Janssens, 2001).

In DR Congo in general, and in the former Orientale Province in particular, cassava deserves special attention in the face of CMD and CBSD, emerging viral diseases are the most devastating diseases.

However, the present study concluded that in the former Orientale province, the fields investigated were infected by CMD, with incidence varying from one province to another (Table1). The highest incidencerecorded reached an average of 68.88% with a severity level 2. The results obtained are similar to those from the study carried out in Bangui by Zinga (2012), which showed an meanincidence of CMD of 71.9%. Unlike the studies carried out in North Kivu by Musubao *et al*. (2022), where the mean incidence of CMD was 39.52% in monoculture and 22.36% in intercropping. Likiti *et al.* (2024) determined the incidence of CMD in Nord-Ubangi province (44.63 ± 6.37%), thiscan be explained by the predominant use of cassava cuttings of local varieties as planting material. The proximity of communities living in this area could easily facilitate the unregulated exchange of infected planting material from one territory/district to another.

For CBSD on the other hand, a moderate incidence was observed in the former OrientaleProvince with mean incidence 17.54% and a severity level 2. The results obtained are not similar to those found by Masinde *et al*. (2016) and Mware *et al*. (2009) in western and eastern Kenya, where CBSD incidences recorded were typically high (5 to 74% and 38 to 93% respectively). They are comparable to the observations reported in east-central Uganda (4 to 64%) by Alicai *et al*. (2007). This reflects the progression of the disease from eastern neighboring countries to areas not yet infected by CBSD in DRCongo.

The quantity of pathogen inoculum (CBSD) is sufficient to observe phenotypic resistant traits in the field. This is known as quantitative resistance, which conduct to reduce the disease rather than its total disappearance. Quantitative resistant explain the low severity (level 2) of CMD and CBSD that varied considerably between provinces, and remained low throughout the former Orientale province compared to others eastern regions of the country, namely North and South Kivu, where a severity level 3 was reported (Bisimwa *et al*., 2012). This suggests that CBSD pressure is more pronounced in the eastern part of the country, the front of the introduction of the CBSD disease of cassava from East to West Africa (Legg *et al*., 2006; 2011).

Results confirm that whitefly abundance for entire former Orientaleprovince was 3 whiteflies/plant. The highest whitefly densities were found in the provinces of Tshopo and Ituri, with 5 whiteflies/plant each, and in the provinces of Bas-Uele and Haut-Uele, with 1 whitefly/plant each.Similar results were obtained by Mware *et al*. (2009) in Kenya, where the population was of 6 to 8 whiteflies/cassava plant in Bondo district. A low whitefly population of one whitefly/cassava plant was recorded in the Kirinyaga district. The results of the present study show that *B. tabaci* outbreaks do not appear to be a major factor in the spread of the disease in the formerOrientale province. The low activity of *B. tabaci* in the spread of CMD in the present study could be explained by their relatively low level of abundance in the areas studied.This is thought to be in direct relation to the cassava cropping system (Macfadyen *et al.,* 2018), varieties grown and environmental conditions, such as temperature and humidity, and field landscape (proximity of fields to main roads) (Katono *et al*., 2021). These factors could influence whitefly abundance and, consequently, their impact on the spread of CMD.

Overall, we found that more cassava cultivars are still resistant in the field to CBSD than to CMD. Given that CMD is an ancient disease and that many infected planting materials have been distributed throughout the provinces in DR Congo, this has led to its spread and extent throughout the country.

Results show that in Tshopo province, the majority of cassava cultivars were asymptomatic to CBSD (38/57 (67%), while fewer cultivars were asymptomatic to CMD (4/57 (7%) out of all cultivars surveyed). Overall, the study identified a higher number of cultivars with quantitative field resistance to CBSD. Quantitative resistance is based on molecular mechanisms involving the interaction of several genes, which pathogens cannot overcome all at once. Whereas those that have been overcome in the face of CBSD are few in number. The low level of severity 2 against CMD can be explained by the complex resistance mechanisms present in the cultivars disseminated by both national and international organizations in the fight against malnutrition and undernourishment in DR Congo. Disseminated resistant cassava may have a type of quantitative resistance that continues to be expressed despite the efforts of pathogens to break this resistance. These results open up a field of study into the resistance mechanisms existing in these cultivars, collected and preserved at IFA Yangambi.

V. Conclusion

The aim of thisstudy was to determine the epidemic level of CMD and CBSD in the Orientale Provinceregion and to identify some cassava cultivars resistant to CMD and CBSD in the field. To achieve this, an epidemiological survey was conducted in the provinces of Tshopo, Bas-Uele, Haut-Uele and Ituri in February 2022. A total of 180 cassava fields of 5 to 9 months old after planting, were surveyed.

The cassava cropping system (intercropping) and the epidemiological parameters of CMD and CBSD (incidence, severity, abundance of whitefly, sources of infection) were evaluated, and the whitefly population was assessed.

As for the whitefly population in our study area, it is relatively very low (1 to 5 white flies), and the CMD pandemic is highly spread in former Orientale Province , in contrast to the CBSD pandemic, which is still at a moderate level. Both viral pandemics are still of low severity (level 2).

The main source of virus infection remains cuttings already infected (57.80%). Overall, there are more in field-resistant cassava cultivars in the region to CBSD than to CMD. These results need to be confirmed using genotyping study.

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