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EPIDEMIOLOGICAL ASSESSMENT OF CASSAVA MOSAIC DISEASE IN A SAVANNA REGION OF THE DEMOCRATIC REPUBLIC OF CONGO

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ABSTRACT

An epidemiological survey was conducted, from September 2009 to January 2010 in 206 famers' fields located across 21 cassava-growing localities of Ngandajika territory in Lomami province (central part of Democratic Republic of Congo (DRC), to determine distribution and status of Cassava Mosaic Disease (CMD). Parameters related to the identification and the evaluation of CMD (incidence, severity and gravity) and number of adult whitefly vector were assessed. CMD was present in all localities surveyed and varied according to the localities and varieties. CMD incidence was low at the INERA station (4.33%) but high in Kafumbu (74.55%). Disease severity was low at the INERA station (1.09) but high in Kafumbu (2.67). Gravity was low at the INERA station (2.99%) and elevated in Quartier Congo (67.82%). The mean of adult whitefly populations varied with sites. However, the whiteflies were more abundant in Mpunga (3.65) compared to the INERA station (1.09). Overall, 71 % of varieties showed varying degrees of sensitivity to CMD. The results of this study revealed that the health status of cassava in Ngandajika is alarming and deserves sustained intervention. Adequate and effective control methods must to be in place to reduce the inoculum levels and the speed of CMD propagation and to limit yield losses caused by this disease.

Contribution/Originality: The results of this study revealed the prevalence, severity and gravity of the Cassava Mosaic Disease (CMD) in the Central region of the Democratic Republic of Congo. Responses of different cassava varieties to CMD infections are described in details across several localities within the targeted region.

1. INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is the most important food crop in the Democratic Republic of Congo (DRC) and is a staple food for more than 800 million people in tropical and sub-tropical Africa (Houngue et al., 2019; Maruthi et al., 2018). It ranks first in volume, and represents nearly 75% of the total food production in the country (INS Annual Statistics of DR Congo, 2015; Khonde, 2001). Its estimated production of 15 004 430 tons made the DRC the second producer of this commodity in Africa, and the fourth on a world scale, after Nigeria (43 410 000 tons), Thailand (26 915 541 tons) and Indonesia (19 988 058 tons) (Faostat, 2010). Its tubers are the main source of calories for about 70% of the Congolese population (Muimba, Muyolo, Mahungu, & Pandey, 1986; Musungayi et al., 2018). Its leaves that represent the main source of proteins, vitamins, and minerals are preferred green vegetables for many families (Jalloh & Dahniga, 1994; Lutaladio, 1985).

This crop can be grown on poor soils, as it requires very few agronomic inputs. It is well adapted to the traditional mixed cropping agricultural systems and its roots can be conserved a long time in soil. In the DRC more than 50% of arable lands for food crops is growing cassava and data recorded for 21-year data from 1990 to 2010 showed that the provinces of Lomami, Kasai, Kasai Oriental and Kongo Central account for over one-fifth, or 21.9% of this crop's area (Mahungu, Tata-Hangy, Bidiaka, & Frangoie, 2014).

Cassava crop can yield up to 80 tons/ha, but it rarely produces at full potential (Massala, 1988). Generally, the level of production remains low in DRC (7 tons/ha in the famers' fields and until 25-30 tons/ha in experimental stations and in the well managed farms) (Tata-Hangy et al., 2004) because of numerous constraints mostly related to the traditional practices (Godo, 1988; Mahungu, 1988). Among these factors that limit its production, we note low productivity farming practices coupled with the lack of inputs, the relative slowness of diffusion of the improved varieties adapted to the local conditions and local culinary requirements, the depletion or reduction soil fertility, the use of local varieties more susceptible to disease and pest attacks (Godo, 1988; Lozano & Terry, 1976; Mahungu, 1988; Muimba et al., 1986).

This low cassava yield reported in DRC declined further in recent years following outbreaks of a severe viral disease, the Cassava Mosaic Disease (CMD). Legg, Owor, Sseruwagi, and Ndunguru (2006) reported that in recent years, the CMD has been a pandemic in Africa and has become one of the most economically important crop diseases causing yield loss ranging from 20 to 90 % for susceptible varieties. It is considered currently as the most damaging constraint to cassava production in the DRC and almost all the provinces are affected and production lowered irretrievably (Obonyo, Tata, Koffi, Asiimwe, & Legg, 2007; Tata-Hangy et al., 2004). The pandemic's impact resulted in a drastic reduction in cassava production, large decreases in the area covered by of cassava crop, marked increases in market prices for cassava food products and planting material, and changes in the relative importance of cassava varieties (Legg et al., 2006).

CMD is caused by cassava mosaic begomoviruses (CMBs) (family *Geminiviridae*; genus *Begomovirus*) (Chikoti et al., 2013; Monde, Walangululu, Winter, & Bragard, 2010). CMBs are transmitted by whitefly vector, *Bemisia tabaci* Gennadius (Dubern, 1994; Fargette, Fauquet, Grenier, & Thresh, 1990; Fargette, Jeger, Fauquet, & Fishpool, 1994; Kufferath & Ghesquière, 1932; Legg, 1994; Zinga et al., 2008) by grafting (Fargette, Thouvenel, & Fauquet, 1987; Pynaert, 1951) or either through using cuttings from infected parent plants for planting material (Busogoro et al., 2008; Fargette & Vie, 1994; Legg & Owor, 2003; Storey & Nichols, 1938; Swanson & Harrison, 1994).

The sustainable way for long-term, large-scale control of this disease in Africa is phytosanitation, which is used to reduce the incidence of disease in a crop, particularly on varieties that suppress virus accumulation in the farming system (Rabbi et al., 2014). Other control methods include the use of tissues culture, selection of disease-free stems for new plantings and removal of diseased plants from crop stands, and vulgarization of resistant variety (Fargette, Colon, Bouveau, & Fauquet, 1996; Legg et al., 2006). However, the use of resistant variety, which appears to be a more effective approach, remains limited because the limited quantities of cuttings and their cost that is prohibitive for access by many farmers (Ambang, Amougou, Ndongo, Nantia, & Chewachong, 2009). In some cases, genetically improved varieties do not possess agronomic characteristics that are sought by farmers (Hillocks & Thresh, 2000). This disease, that was first reported in 1894 (Hillocks & Thresh, 2000; Legg & Fauquet, 2004; Thresh, Fargette, & Otim-Nape, 1994) and for which the only effective means of control is the selection and use of resistant cultivars, continues to threaten cassava production and food security of the Congolese population. It is essential to implement cost-effective measures to limit the losses caused by this disease. In this context, surveys were conducted in various agro-ecological zones of cassava production in the Territory of Ngandajika to determine the health status of cassava. This will provide information on the prevalence of disease that will be considered in the implementation of integrated disease management strategies.

2. MATERIALS AND METHODS

2.1. Survey routes, Description of survey area and Field Sampling

The surveys were conducted during the cropping season A from September 2009 to January 2010 at the National Institute for the Study and Agronomic Research (INERA) Station and at twenty cassava-growing localities. They include, Gandajika, Kafumbu, Kaniana, Kanyaka I, Kanyaka Mupanga, Kaseki, Luanga, Mande, Mpasu, Mpasu Mutombo, Mpemba Nzeo, Mpiana, Mpoyi, Mpunga, Mulamba I, Mulamba II, Mulumba, Nsona, Quartier Congo and Yamba within the Ngandajika territory (DRC).

Ngandajika (6°45'00"S, 23°58'01"E) is bordered by the territories of Kabongo in the East, Tshilenge across Luilu river in the West, Katanda and Kabinda in the North, and Luilu in the South. It is located 90 km from Mbuji-Mayi (Mukendi et al., 2019).

The vegetation of this region consists mainly of grassy Guinean savannahs; dominated by *Imperata cylindrica* (Crabbe & Totiwe, 1979) interspersed by semi-deciduous, subequatorial and Guinean forest galleries (or isolated massifs) along rivers and streams.

Ngandajika soils are characterized by heavy and sandy clay texture and good structure, the clay fraction is small important but varying in different localities (Muyayabantu, Nkongolo, & Kadiata, 2012). Their clay content varies between 20 and 50%, depending on the depth. These are highly weathered soils derived from rocks of the Bushimaie system characterized by a pH of 5.4 to 6.2 with an exchange capacity of around 4 meq / 100 g of soil.

Ngandajika territory falls within the Aw_4 climate type according to Köppen classification characterized with 4 months of dry season (from mid-May to August) coupled with 8 months of rainy season, sometimes interrupted by a short dry season in January/February. The average daily temperature is 25°C and the annual rainfall is close to 1500 mm (Muyayabantu et al., 2012).

In each selected locality, an exhaustive survey (except refusal or difficulty to contact the Owner of the field) of cassava fields was conducted as a basis for sampling. A sample of at least 10 fields was selected in each site. We chose at random from a predetermined list, the fields to be inspected. Overall, 206 farmers' fields were selected. These fields were located either around family houses or away from home in Savannah. The itinerary and fields sampled were selected on the basis of their accessibility and the importance and extend of cassava crop. The geographic coordinates (longitude, latitude and altitude) for each sampling site and field were recorded using a Global Positioning System (GPS; etrex summit Garmin) device. The localities covered during the survey are shown in Figure 1.

2.2. Field Survey Data Parameters

The methodology for collecting data is based on the identification of plants with typical CMD symptoms. Fields with crops between 1 and 14 months old were considered. All data on diseases were recorded from 30 randomly selected plants across two diagonals (15 plants per diagonal) of the field (Ntawuruhunga et al., 2007; Obonyo et al., 2007; Tata-Hangy et al., 2004). Data collected included the CMD incidence, severity and gravity, the abundance of adult *Bemisia tabaci* and the names of the cassava varieties. In addition, the age of fields, cropping system and phytosanitation were also recorded.

a) *CMD Incidence:* at any particular time, was calculated as a percentage of plants with CMD symptoms in each cultivar in the field.

$$CMD\ Incidence = \frac{Number\ of\ infected\ plants}{Total\ of\ observed\ plants} \times 100$$

b) *CMD Severity:* which was used to determine the level of symptom expression, was assessed using the 1 to 5 scale (Hahn, Terry, & Leuschner, 1980) in which:

1 = no symptoms (apparent field resistance); 2 = mild chlorotic pattern over entire leaflets or mild distortion only at the basis of leaflets with the rest of the leaflets appearing green and healthy; 3 = strong mosaic pattern

throughout leaf, narrowing and distortion of lower 1/3 of leaflets; 4 = severe mosaic, distortion of 2/3 of leaflets and general reduction of leaf size; 5 = severe mosaic, distortion of 4/5 or more leaflets, twisted and misshapen leaves.

c) *CMD Gravity:* or the attack rate of leaves was calculated as the percentage of leaf per plant showing disease symptoms.

$$CMD\ Gravity = \frac{Number\ of\ leaves\ with\ symptoms}{Total\ number\ of\ leaves\ per\ plant} \times 100$$

d) *Abundance of adult B. tabaci::* The numbers of adult *B. tabaci* were counted on the underside of five topmost expanded leaves of the tallest shoot for each of the 30 plants sampled in each field.

This is because the adults feed preferentially and oviposit on the youngest immature leaves (Fargette, 1985; Fargette 1985; Gameel, 1977; Khalifa & El-Khidir, 1964). Each leaf was held by the petiole and gently inverted so that the adults present on the lower surface can be counted (Fargette, 1985; Fishpool et al., 1995). Counting was done in the relatively cool periods of daylight, between 6.00 and 10 am or between 4.00 and 6.00 pm, when the insects are less active than at other times of the day (Sseruwagi, Otim-Nape, Osiru, & Thresh, 2003).

2.3. Classification of Cassava Cultivars for Resistance to CMD

Agglomerative hierarchical clustering (AHC) or dendrogram was developed to classify cassava varieties based on:

a) *CMD Incidence.* The incidence "0%" represented highly resistant (HR), incidence class [1-30%] resistant (R), incidence class [31-50%] susceptible (S) and incidence class [51-100%] highly susceptible (HS) genotypes.

b) *CMD severity scores* as described by Houngue et al. (2019). The severity score "1" represented highly resistant (HR), severity score class [1.1-2] resistant (R), severity score class [2.1-2.4] susceptible (S) and severity score class [2.5-5] highly susceptible (HS).

2.4. Data Analysis

Mean and standard error values were calculated for all factors measured both for each field, as well as for each locality using R software (version R-2.9.0 and 3.5.0).

3. RESULTS

3.1. Incidence, Severity and Gravity of CMD and Number of Adult Whiteflies (B. Tabaci) Per Locality

Based only on visual assessment symptoms, CMD was present in all localities surveyed (Table 1). Except at the INERA station, where the percentage of fields infested was low (20%), other localities showed high levels of percentages of fields ranging from 80 and 100%. The incidence, severity and gravity varied according to the localities and the cultivars. CMD incidence was low in fields surveyed at the INERA station (4.33%) and Gandajika (29.26%) where famers have easy access to genetically improved varieties. The disease incidence was moderate in Kaseki (47%), Kanyaka Mupanga (54.55%), Luanga (42.12%), Mpasu (43.85%), Mpasu Mutombo (44.72%), Mpiana (32.33%), Mpoyi (53.33%), Mpunga (42.62%), Mulamba I (32.12%), Mulamba II (49.49%) and Yamba (43.61%) where the pressure of disease was also low. The incidence was high in Kafumbu (74.55%), Kaniana (65.67%), Kanyaka I (71.8%), Mande (68.18%), Mpemba Nzeo (59.17%), Mulumba (68%), Nsona (56.33%) and Quartier Congo (72.22%) where genetically improved varieties were absent. Overall, the mean incidence for all localities was 50.25%.

CMD severity was low (≥1) at the INERA station, moderate (≤2) in Gandajika, Kaniana, Kanyaka I, Kanyaka Mupanga, Kaseki, Luanga, Mpasu, Mpasu Mutombo, Mpemba Nzeo, Mpiana, Mpoyi, Mpunga, Mulamba I, Mulamba II, Nsona and Yamba but relatively high (≤3) in Kafumbu, Mande, Mulumba and Quartier Congo. CMD mean severity for the area surveyed was moderate (2.03). The greatest number of plants had no (1) or moderate (3) symptoms (Figure 2). Overall, 49.4% of the plants observed in 21 localities had no symptoms (1), 30.01% had moderate symptoms (3), 10.16% had severe symptoms (4), 9.5 % had mild symptoms (2) and 0.96% had very severe symptoms (5).

CMD gravity was lowest at the INERA station (2.99%). The level of infection at other locations varied; Gandajika (27.15%), Mpasu (27.33%), Mpiana (24.92%) and Mulamba I (24.65%) but highest in Kafumbu (59.79%), Kanyaka I (64.32%), Mande (52.66%), Mulumba (51.76%) and Quartier Congo (67.82%). It also appears that *B. tabaci* was present in all localities surveyed (Table 1). The mean adult whitefly populations varied with site. However, the whiteflies were most abundant in Mpunga (3.65) but less abundant in INERA station (1.09).

3.2. Incidence, Severity and Gravity of CMD and Number of Adult Whiteflies (B. Tabaci) Per Cultivars

The inventory carried out in farms of the study areas showed that cassava producers use a variety of materials. 10 improved varieties (Butamu, Disanka, GA006/045, Gandajika, I004/024, Mbakana, Mvuama, Nsansi, Sadissa and TME 419) and 18 local varieties (Kalenda Maluvu, Kamana Mabanza, Kasala, Katshi Kafika, Katshi Kalumeta, Lakilomba, Luenyi, Luputa, Mandamu, Mesa Ntenta, Mpoyi Bisaku, Muhula Tshina, Mutombo Tshiomba, Mwana wa Mpiana, Nzaza, Tshilobo, Tshimahingu and Tshimpondja) were identified during survey. There was little production of genetically improved varieties in surveyed area.

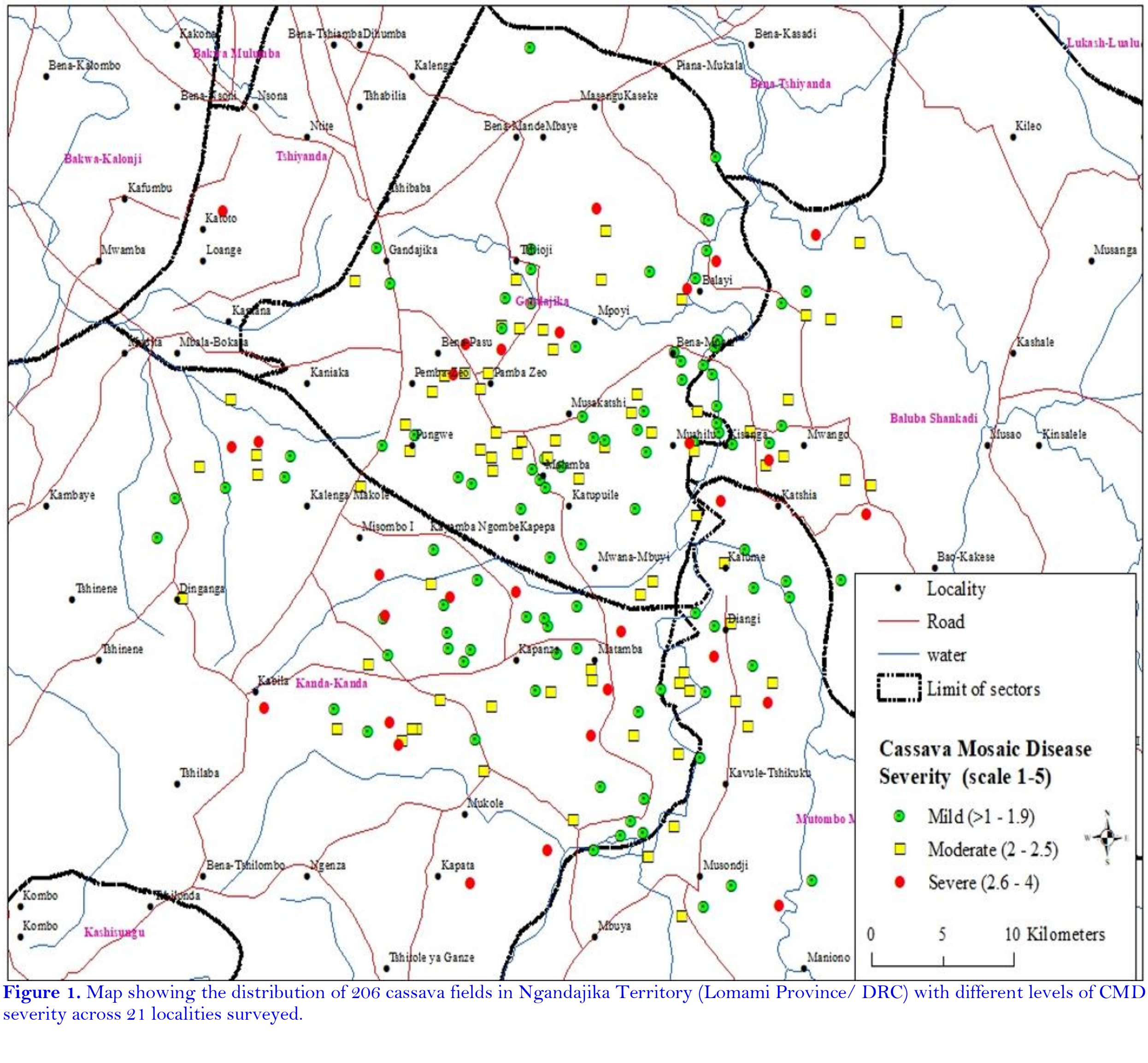

Figure 1. Map showing the distribution of 206 cassava fields in Ngandajika Territory (Lomami Province/ DRC) with different levels of CMD severity across 21 localities surveyed.

Table 1. Incidence, severity, and gravity of Cassava Mosaic Disease (CMD) and number of adult whiteflies (*B. tabaci*) per locality in Ngandagika Territory.

Locality	Number of fields surveyed	Fields attacked (%)	CMD Incidence (%)	CMD Severity	CMD Gravity (%)	Adult *B. tabaci* per plant
Gandajika	8	100	29.26	1.79	27.15	1.12
Inera	10	20	4.33	1.09	2.99	1.09
Kafumbu	10	100	74.55	2.67	59.79	1.3
Kaniana	10	100	65.67	2.21	45.37	2.1
Kanyaka I	10	100	71.8	2.33	64.32	2.54
Kanyaka Mupanga	10	80	54.55	2.01	48.08	1.52
Kaseki	10	100	47	2.07	41.3	1.48
Luanga	10	90	42.12	2.07	31.49	1.52
Mande	10	90	68.18	2.45	52.66	1.58
Mpasu	10	100	43.85	1.88	27.33	2.37
Mpasu Mutombo	10	100	44.72	1.83	36.25	2.24
Mpemba Nzeo	10	100	59.17	2.11	44.93	2.64
Mpiana	10	100	32.33	1.67	24.92	2.43
Mpoyi	8	100	53.33	1.94	47.42	1.76
Mpunga	10	90	42.62	1.87	34.21	3.65
Mulamba I	10	100	32.12	1.65	24.65	1.66
Mulamba II	10	100	49.49	2.08	38.28	2.54
Mulumba	10	100	68	2.46	51.76	2.66
Nsona	10	100	56.33	2.22	42.32	2.42
Quartier Congo	10	100	72.22	2.6	67.82	1.58
Yamba	10	80	43.61	1.73	35.03	2.22
Mean		92.86	50.25	2.03	40.38	2.02
Standard error		3.91	3.78	0.08	3.29	0.14

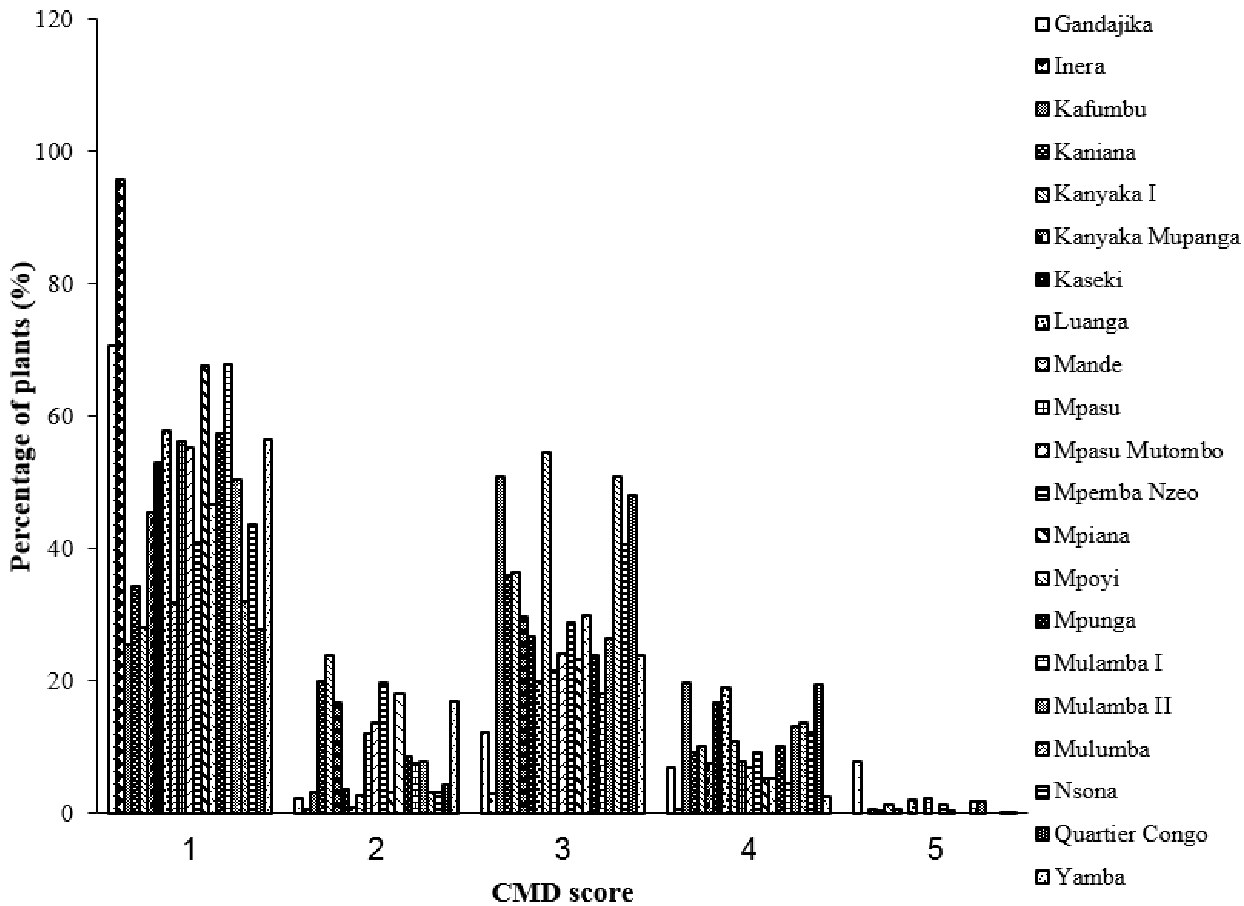

Figure 2. Comparison of CMD severity among the localities. The list at the right side represents the names of different localities.

The data in Table 2 shows that the genetically improved varieties are planted in 7.26% of fields compared to local materials that represent 92.8% of the fields surveyed. These local materials usually have vernacular names that have diversified meanings. The most frequently cultivated variety was Kamana Mabanza (26.81%).

Data in Table 2 also shows that the majority of varieties in this region were susceptible to CMD. Young crops (2 - 4 months old) had a high incidence (42.13%) compared to those with more than 4 months old (23.33%). Butamu, Disanka, Gandajika, I004/024, Mbakana, Nsansi, Sadissa, and TME419 varieties showed no CMD symptoms. Luputa showed the highest incidence (82.22%), and severe symptoms (3.09), along with the highest gravity (76.36%). Whiteflies were present on plants of all cultivars. Their number in all cases ranged from 0.37 to 4.96. The lowest number of whitefly was found among cultivars GA006/045 and I004/024 with respective mean values of 0.47 and 0.37. Whiteflies were abundant on the cultivar Mwana wa Mpiana (4.96).

During the investigations, one noticed also that intercropping is widely practiced in Ngandajika. Groundnut, maize, niebe, soybeans and common beans were the most frequently crops intercropped with cassava. In 61.65% of the fields, cassava was intercropped with the maize while in 23.93% of fields, cassava was cultivated alone. The phytosanitation has only been applied in 5.08% of fields.

Table 2. Incidence, severity and gravity of Cassava Mosaic Disease (CMD) and abundance of adult *B. tabaci* per cultivar in Ngandajika Territory.

Cultivar	Number of fields	Age (Month)	CMD Incidence (%)	CMD Severity	CMD Gravity (%)	Adult *B. tabaci* per plant
Butamu	1	2	0	1	0	1.83
Disanka	1	9	0	1	0	0.97
GA006/045	1	9	16.67	1.37	11.33	0.47
Gandajika	5	5	0	1	0	1.55
I004/024	1	9	0	1	0	0.37
Kalenda Maluvu	28	5	37.14	1.77	30.59	2.08
Kamana Mabanza	63	6	64.71	2.29	47.81	1.82
Kasala	3	7	61.11	2.68	50.77	1.3
Katshi Kafika	1	3	63.33	2.47	62.94	1.37
Katshi Kalumeta	1	9	20	1.33	15.03	0.73
Lakilomba	3	5	22.22	1.51	11.08	2.06
Luenyi	21	4	40.48	1.94	36.75	1.36
Luputa	3	2	82.22	3.09	76.36	2.54
Mandamu	3	2	36.67	1.72	20.52	2.41
Mbakana	2	9	0	1	0	2.18
Mesa Ntenta	2	3	60	2.32	51.67	1.98
Mpoyi Bisaku	2	2	36.67	1.73	25.82	1.68
Muhula Tshina	1	2	36.67	1.57	19.86	2.27
Mutombo Tshomba	3	7	81.11	2.78	67.44	3.01
Mvuama	1	2	33.33	1.67	31.11	1.53
Mwana wa Mpiana	5	4	26	1.52	16.25	4.96
Nsansi	1	2	0	1	0	2.67
Nzaza	12	7	26.95	1.62	20.52	1.23
Sadissa	3	7	0	1	0	1.43
TME419	1	9	0	1	0	0.6
Tshilobo	61	3	64.86	2.25	55.36	2.64
Tshimahingu	2	11	20	1.45	14.32	0.77
Tshipondja	4	2	67.5	2.55	54.44	2.67
Mean (n=235)		5.23	32.06	1.70	25.71	1.80
Standard error		0.57	5.14	0.12	4.53	0.18

3.3. Classification of Cassava Cultivars

Cassava varieties were grouped into four classes based on the incidence and severity of CMD: C1, C2, C3 and C4 (Figure 3 and 4). Class C1 for highly resistant cultivars (HR), Class C2 for resistant cultivars (R), Class C3 for susceptible cultivars (S) and Class C4 for highly susceptible cultivars (HS).

a) Based on CMD incidence

Based on the CMD incidence, the classification provided in Figure 3 showed that Class C1 included eight highly resistant varieties (Butamu, Disanka, Gandajika, I004/024, Mbakana, Nsansi, Sadissa and TME 419), Class C2 six resistant varieties (GA006/045, Katshi Kalumeta, Lakilomba, Mwana wa Mpiana, Nzaza and Tshimahingu), class C3 grouped six susceptible varieties (Kalenda Maluvu, Luenyi, Mandamu, Mpoyi Bisaku, Muhula Tshina and Mvuama), and finally class C4 included eight highly susceptible varieties (Kamana Mabanza, Kasala, Katshi Kafika, Luputa, Mesa Ntenta, Mutombo Tshomba, Tshilobo and Tshipondja).

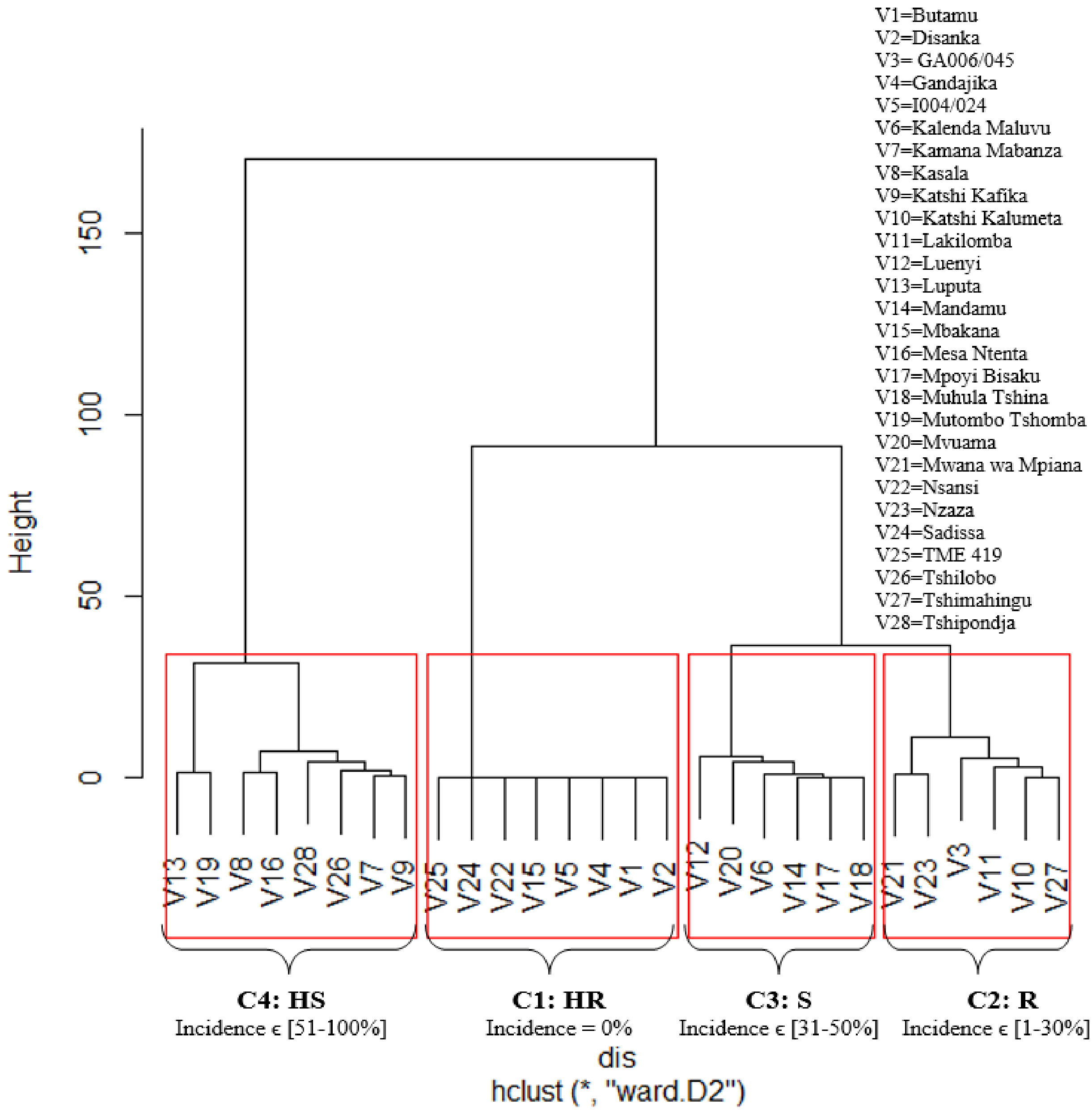

Figure 3. Classification of cassava cultivars for resistance to CMD based on incidence. V1 to V25 on the list represent of different cultivars.
Note: V= variety; C1=Class 1, C2=Class 2, C3=Class 3, C4= Class 4;
HR=Highly Resistant varieties, R=Resistant varieties, S=Susceptible varieties, HS=Highly Susceptible varieties.

b) Based on CMD Severity

Based on the CMD severity, the classification provided in Figure 4 revealed that Class C1 included also eight highly resistant cultivars (Butamu, Disanka, Gandajika, I004/024, Mbakana, Nsansi, Sadissa and TME 419), Class C2 12 resistant cultivars (GA006/045, Kalenda Maluvu, Katshi Kalumeta, Lakilomba, Luenyi, Mandamu, Mpoyi Bisaku, Muhula Tshina, Mvuama, Mwana wa Mpiana, Nzaza and Tshimahingu), class C3 three susceptible cultivars (Kamana Mabanza, Mesa Ntenta and Tshilobo), and class C4 five highly susceptible cultivars (Kasala, Katshi Kafika, Luputa, Mutombo Tshomba and Tshipondja).

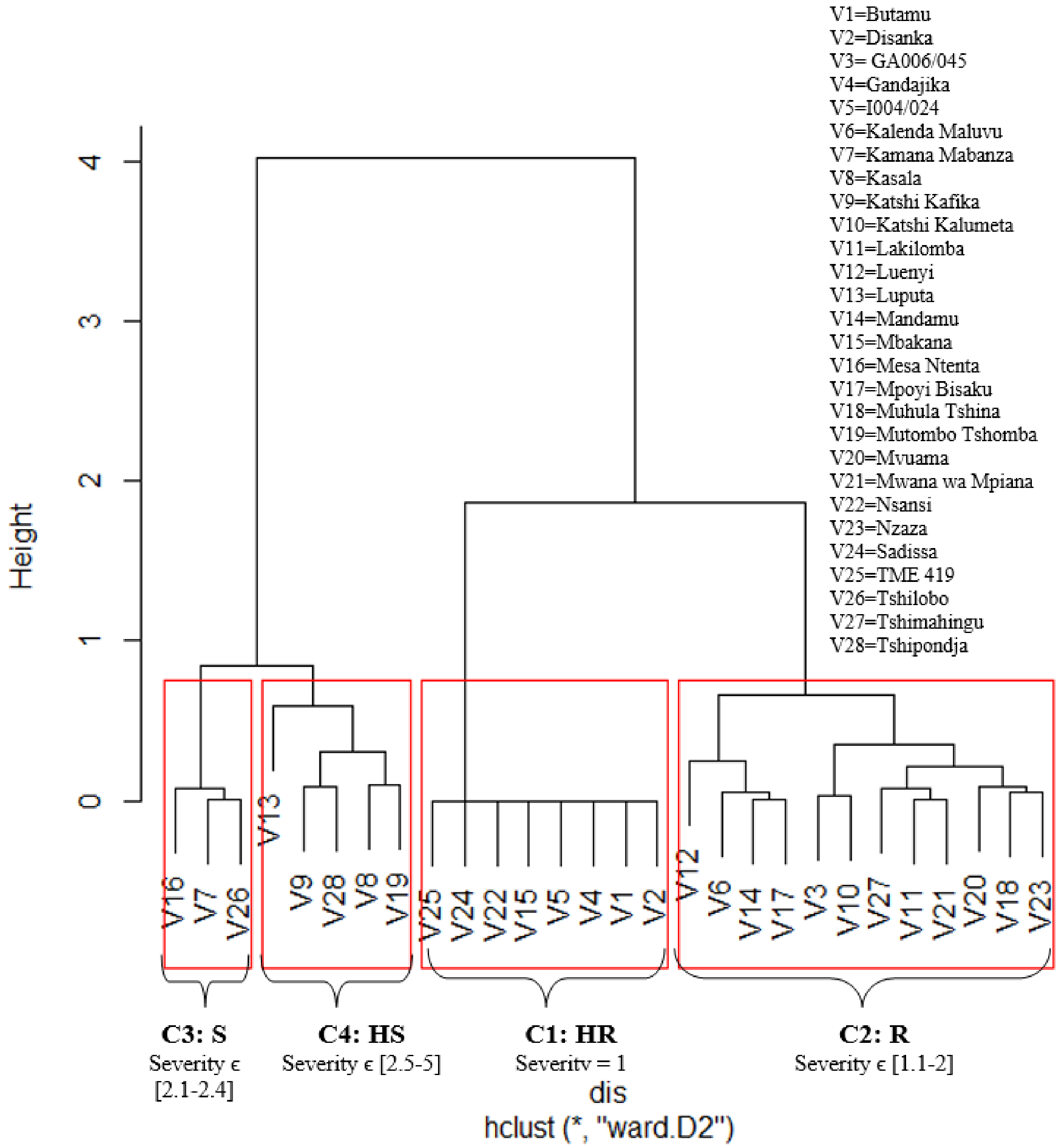

Figure 4. Classification of cassava cultivars for resistance to CMD based on severity score. V1 to V25 on the list represent different cultivars.

Note: V= variety; C1=Class 1, C2=Class 2, C3=Class 3, C4= Class 4;
HR=Highly Resistant varieties, R=Resistant varieties, S=Susceptible varieties, HS=Highly Susceptible varieties

4. DISCUSSION

The results of the present study showed that the Cassava Mosaic Disease (CMD) was present in all surveyed localities with low to severe symptoms and revealed the strong need for interventions. The distribution of the disease in this region is related directly to the characteristics of varieties that are cultivated. There is a big inventory of cassava varieties available and planted by farmers in Ngandajika. Their choice is based on several criteria related not only to the specific characteristics of varieties, but also to the environment factors, the constraints of production and marketing, eating habits, the ability to storage and conservation in the soil. Difficulties in the supply and unavailability of genetically improved varieties, despite the proximity of the INERA station, could explain the interest to local varieties. And in most of surveyed fields, the rapid spread of CMD is due to the routine use of infected stem cuttings, as planting material. Mollard (1988) reported that the important need in cuttings during planting lead often to farmers using materials carrying the virus or sensitive to CMD. This situation is likely to increase the viral load and sustain the CMD in this region. This observation is in agreement with Houngue et al. (2019) and Kilumba (1985) on the production system of cassava in Ngandajika since 75% of cultivars planted were also sensitive to CMD.

The CMD incidence, severity and gravity were elevated in local cultivars and lower in genetically improved varieties. In all localities, the incidence varied between 4.33% and 74.33%, the values of severity ranged from 1.09 to 2.67, and gravity varied between 2.99 and 67.82%. These results showed that 55% of infected varieties were between 1 and 4 months old. This finding agrees with Asare, Galyuon, Asare-Bediako, Sarfo, and Tetteh (2014) that high incidence of CMD is at 12 weeks after planting. The high variation in susceptibility to CMD was probably due to differences in their genetic make-up (Prasangika, Salim, & Razak, 2008) and the disease pressure.

However, it is clear that early infection is more dangerous than a late contamination (Fargette, Fauquet, Raven, Laville, & Thouvenel, 1985; Robertson, 1988) the first leading inexorably to huge losses in production of tubers than the second.

The presence of whiteflies (*Bemisia tabaci)* was observed in all fields, but the number of flies recorded was very low number (1 to 5 adult whiteflies per plant) in all the localities and cultivars. This data showed that the differences in whitefly population were found on resistant than susceptible genotypes of cassava. Similar observations were reposrted by Asare et al. (2014). The low number could be related to plant diversity in association with cassava. Several authors show that these associations reduce the population dynamics of whiteflies and symptom expression (Ahohuendo & Sarkar, 1995; Otim-Nape & Ingoot, 1986; Thresh, 1988). In many experiments in cages (Abdullahi, 2001) the total number of adult whiteflies had no influence on the incidence of CMD. However, Chant (1958) and Seif (1981) have shown that infection rates are much higher than the number of whiteflies contaminated itself is high. If we compare their results to field conditions, it seems that for some varieties only a small number of infected whiteflies is necessary to transmit the disease. Muengula-Manyi et al. (2012) and Robertson (1988) reported that the transmission of CMD from one cassava plant to another depends upon the availability of inoculum and both density and activity of the whiteflies *Bemisia tabaci* vectors.

About the intercropping, the general synthesis of the national reports on the CMD and its control in DRC reported by Mahungu (1988) confirms that in traditional environment, cassava was intercropped with other crops such as maize, groundnut, rice, beans, etc. Although, there are various reasons that incite the farmers to practice intercropping, the most important is that the total productivity and the general income of a soil unit are raised more in associated culture that in monocropping (Ikeorgu, Wahua, & Ezumah, 1985). Besides, the farmers protect the maintenance of their main culture. And the type of intercropping used is function of the farmer's food and financial needs and the pedo-climatic conditions.

The eradication of plants with symptoms (phytosanitation) was nearly probably absent in all sites because of the addition of work for the growers and especially of the loss of harvest that will ensue some.

5. CONCLUSION

Based on the results of this study, improved genotypes were high resistant by CMD. But local genotypes showed that highest and sensible of CMD with Katshi Kafika, Luputa, Kamana Mabanza, Kasala, Mesa Tenta, Mutombo Tshomba and Tshilobo. The use of resistant varieties by farmers would be required and may reduce the possibility of extending the CMD.

Selection for resistance was seen as a possible strategy of a large-scale and long-term CMD control (Fargette, Colon, Bouveau, & Fauquet, 1996; Guthrie, 1988). However, the performance of resistance varieties cannot be guaranteed under certain conditions. Increasing the inoculum pressure, agro-ecological changes and the explosion of vector populations can have a significant impact on the expression of resistance. The use of resistant cultivars seems more effective in this case remains limited, because the quantities of cuttings offered are below demand, and when available, the cost seems high for some farmers. Action must be taken to improve the local plant material. Characterization of viral strains inducing CMD and repeated annual surveys over the whole of the DRC could permit to determine the spread of disease. This will allow an immediate implementation of control strategies against this disease. Many efforts will be required to implement in the region the CMD pandemic management programs based on the dissemination and multiplication of CMD-free planting material of resistant varieties in association with phytosanitation.

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