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Incidence and Severity of African Cassava Mosaic in Mubugu and Kalima Fields in Kalehe Territory, Eastern Democratic Republic of Congo

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ABSTRACT

Background: Since cassava is a staple crop whose roots and leaves serve as a staple food in the Democratic Republic of the Congo in general and in Kalehe in particular, efforts to increase its productivity face numerous constraints, among which diseases, particularly the endemic form of mosaic disease, play a significant role.
Aims: This study aimed to assess the incidence and severity of African cassava mosaic (ACM) disease in two clusters within the Kalehe territory in order to propose potential solutions to limit its spread and proliferation.
Methods: To achieve this, surveys were conducted in 200 cassava fields. Two techniques, specifically analysis of variance and correlation analysis using Stata software, enabled us to interpret the field data.
Results: The research results showed that the level of attack by African cassava mosaic virus on cassava was high in the Kalehe territory. ACM was present in both groups. The highest incidence of ACM was 56.39% in Kalima and 56.030% in Mubugu. By locality, the highest incidence of ACM was 57.3% in Mafuo, Makuta (56.3%), and Kashewe (56.8%), followed by Makwe (55.99%), Mushunguti (55.99%), Lukando (55.99%), Kabare (55.9%), Misima (55.99%), Cigoma (55. 8%), and Irangi (55.8%), with an overall average for these 10 localities of 56.21%. In addition, all the varieties identified in the fields at Kalehe, notably Namale, Nambiyo, Elona, and Sawasawa, were susceptible to African cassava mosaic, with relative incidences of 73.5%, 72.26%, 38.99%, and 39.06%, respectively, and a high severity level ranging from 2 to 3. There was a negative relationship between mosaic severity and variety, i.e., the lower the level of mosaic severity, the less diseased the varieties. Hence, this study highlights local varieties, even though research regularly develops and disseminates improved varieties resistant to African cassava mosaic.
Conclusion: African cassava mosaic disease showed a high incidence and severity across cassava fields in the Kalehe territory, indicating that the disease is widely distributed in the study area. All identified local cassava varieties were susceptible to the disease, highlighting the need for resistant varieties and improved disease management strategies.

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1. Introduction

Cassava (*Manihot esculenta Crantz*) is an excellent and inexpensive source of calories for most people in many countries worldwide (Donald, 1998). It is consumed by 1 billion people worldwide, including 500 million living in the tropics and below the Sahara (Dumat & Maris, 2016). In addition to this main role, it contributes to improving the income and food security of over 800 million people in the tropics (Bokanga, 1994; FAOSTAT, 2023). According to the Collaborative Study on Cassava in Africa, cassava is a more important source of income for many households than other crops (Nweke, 1996). Once considered a crop grown by people in poverty, cassava has now become a source of industrial raw material and an essential contributor to food security, poverty reduction, and, beyond that, economic growth (Ntawuruhunga et *al*., 2002; Ganza, 2019).

Despite these multiple advantages, cassava cultivation faces several challenges, notably rudimentary cultivation practices, declining soil fertility levels, and numerous diseases, principally mosaic, whose severe epidemiological form is invading the old varieties grown by producers (FAOSTAT, 2007; Mahungu, 2014, Thomas et al., 2025a, Thomas *et al.,* 2025b).

Mosaic disease has become a persistent and significant threat to cassava production and people's food security. It is caused by a virus transmitted either by an insect vector, the whitefly (*Bemisia tabaci*), or by infected planting material. Symptoms of mosaic include irregular light-green, yellow, or white spots on leaves and leaf deformation, reducing photosynthetic activity and leading to plant stunting (Ntawuruhunga et *al*., 2002).

Thus, its effects on yield range from reductions to total yield loss, depending on the cassava variety grown and environmental factors, but mosaic alone generally causes yield losses of 20-60% (Legg *et al.,* 2015). Africa's estimated mediocre yield of 7 to 8 tonnes of tubers/ha is probably mainly due to the almost ubiquitous presence of African cassava mosaic. Losses due to this disease are difficult to assess (Guthrie, 1999). It is severe and decreases sharply depending on which varieties prove more susceptible (Alimasi, 2011). In East Africa, production losses due to disease damage are estimated at 20%-95%, depending on the variety and timing of infection (Henry et *al*., 2021). In the Democratic Republic of Congo (DRC), mosaic causes yield losses ranging from 77.5% to 97.3% when cassava plants are infected through cuttings. It is the most important biotic constraint to cassava production (Bulonza et *al*., 2023).

Although cassava mosaic disease is present in the Kalehe district and is known to 70% of the farming population (WAVE, 2020), its incidence and severity continue to affect cassava production, thereby impacting the incomes of smallholder farmers, who are the main producers (Patil & Fauquet, 2009) and who remain strongly attached to local varieties even though research regularly develops and disseminates improved varieties resistant to African cassava mosaic virus.

Unfortunately, no study on the actual impact of the disease on local cassava varieties had previously been the subject of participatory research in the Kalehe territory. To this end, we believed it was appropriate to assess the impact of mosaic disease on the local varieties most commonly cultivated by producers in the area. Specifically, this study aims to assess the incidence and severity of African cassava mosaic disease in the Kalehe territory in order to answer the question: What is the level of African cassava mosaic disease infestation in Kalehe?. We estimate that the incidence of African cassava mosaic virus in the Kalehe district is high and varies from one environment to another, or from one variety to another.

The novelty *of this study lies in assessing the incidence and severity of African cassava mosaic disease on local cassava varieties cultivated in the Kalehe territory, Democratic Republic of Congo.*

2. Methods

2.1 Description of The Study Environment

The Kalehe territory is one of eight in the province of South Kivu (DRC). Located north of Bukavu and the Kabare territory, it covers an area of 512,600 hectares (5,126 km²) and extends from 2° 16' 26" south latitude to 28° 54' 58" east longitude. The entire Kalehe territory lies in the high-altitude zone, with an altitude ranging from 1,655m to the level of Lake Kivu (Katunga *et al.,* 2020). Its northern boundary marks the border with North Kivu (Walikale and Masisi territories), while its eastern part is bounded by Lake Kivu, which itself forms the natural border with the Idjwi territory and Rwanda. The western part of the territory borders Shabunda territory and the southern part Kabare (Katunga et *al*., 2020; Williams et *al*., 2014). Figure 1 shows their geographical location.

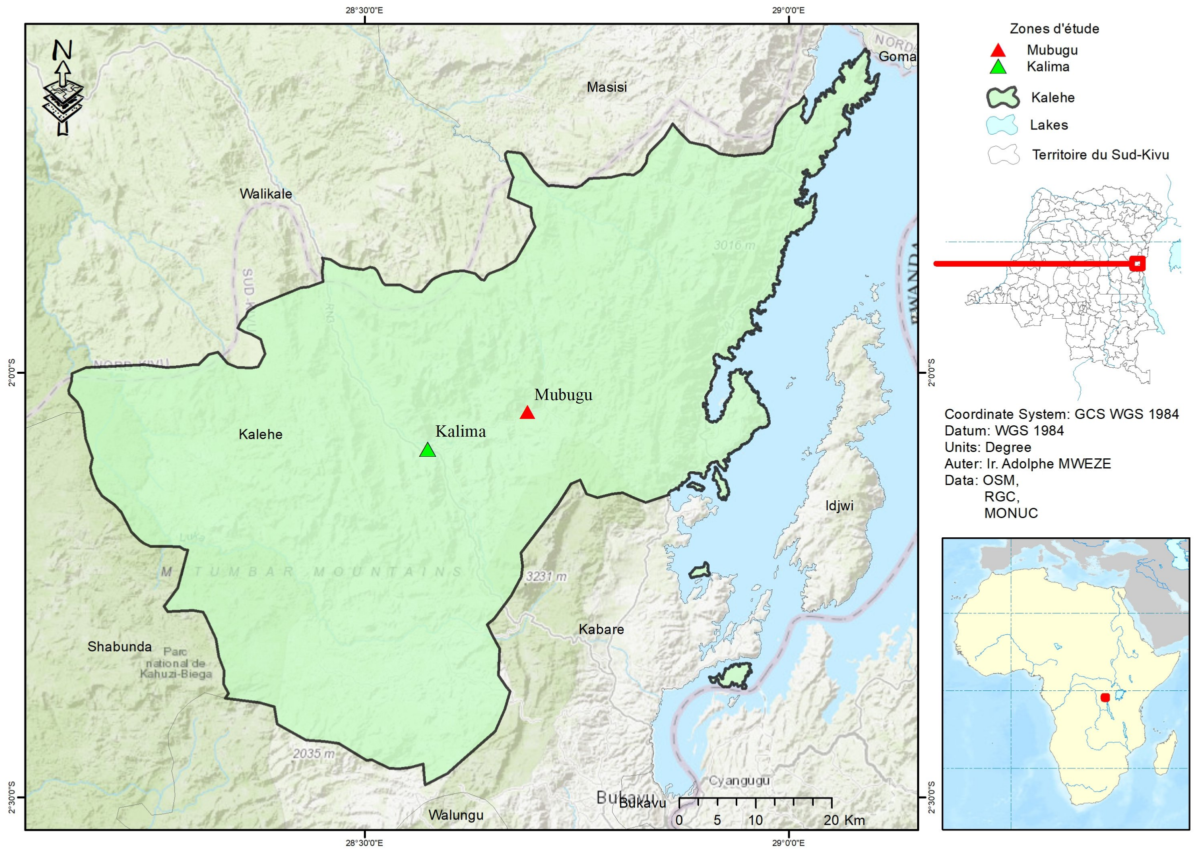

Figure 1. Presentation of the Kalehe territory (Source: Author).

According to the Köppen Aw classification, the Kalehe territory as a savannah climate with a dry winter. There is a 4-month dry season from late May to September and a longer rainy season. It is characterized by an average annual temperature of 18°C, with rainfall averaging between 1,300 and 1,800 mm per year. Studies conducted by Hounkponou *et al.* (2020) show that the territory recorded a record heat of 35°C on Sunday February 5, 2006 and a record cold of 2°C on Friday May 19, 1978. Average temperatures range from 17°C to 20°C, with a daily temperature range of 10°C (Chidumayo et *al*., 2011). Hot days, especially during the dry season, alternate with cold nights. The territory is characterized by a dance forest to the west, which is disappearing due to excessive deforestation of this grassy savannah caused by the population explosion and war in the Grand Lacs region (Déogracias, 2009).

The economy of the Kalehe territory is based on agriculture, livestock breeding, small-scale trade and fishing. Agriculture alone accounts for over 90% of the territory's economy. The most widely grown crops are manioc, groundnuts, beans and oil palm (OCHA, 2023 ; Faugère, 1989).

Kalehe has predominantly clay soil, sandy clay soil and wet soil characteristic of swampy valleys towards the banks of small rivers and in hill basins.It is worth noting that these soils are important and arable in the sense that they are effective for the production of food and market produce, such as cassava, beans, groundnuts, maize, sorghum, tomatoes, eggplants, onions and perennial crops. On some hillsides, the soil is leached, which compromises its fertility for good agricultural activity, and it is for agropastoral use (Munyuli et *al*., 2017). Moreover, maize prefers nitrogen-rich, well-tilled soil.

2.2. Data Collection

2.2.1 Sampling

Our study population consists of cassava fields in the Kalehe territory, specifically in the Mubugu and Kalima sub-districts, during the period covered by our study. The aim is to assess the incidence and severity of cassava pests found in the cultivated fields. To determine the sample for our study (cassava fields), a simple random sampling method was used to achieve the sample size pre-calculated using Cochran's formula (Reny-Nolin, 2012) :

$$n = (Z - scores)^2 * \frac{p*(1-p)}{e^2} \qquad (1)$$

With:

- n = sample size n calculated.
- Z-score = confidence level (equal to 1.96 for 95% confidence) - reduced normal distribution.
- p = estimated proportion of the population with the characteristic studied in the study.
- When this proportion is ignored, a value of p = 0.5 will be used.
- e = margin of error (set at 6.9%).

And so,

$$n = (1{,}96)^2 * \frac{0{,}5 * (1 - 0{,}5)}{0{,}069^2} = 200 \qquad (2)$$

Our sample consisted of 200 cassava fields surveyed in the Kalehe territory.

a) Survey procedure

After selection of the intervention areas, a total of 2 clusters (Mubugu and Kalima), and within each cluster 5 localities were selected, from which 20 fields per locality were sampled for surveys based on the following main indications: (1) Disease incidence: number of infected plants per total number of plants observed; (2) disease severity observations: rating on the 0 to 5 and 1 to 5 scale of African cassava mosaic; (3) farmers' knowledge of ACM management for a realistic approach.

In each locality, 30 cassava plants per field were selected by diagonal observation, including 10 plants on the diagonals and 5 plants on the medians, in the fields of 20 farmers, i.e. 600 plants per locality.

The selected plants were examined for the following parameters: (1) African cassava mosaic symptoms on at least one plant; (2) severity rating on infected plants according to the ACM scale (1 to 5).

2.3. Measuring the Incidence and Severity of Cassava Mosaic

Average incidence and severity in the field are obtained using the following formulas (Bulonza et *al*., 2023):

$$\text{Incidence} = \frac{\text{Number of plants showing disease symptoms}}{\text{Total number of plants observed}} \times 100. \qquad (3)$$

According to Mouketou *et al.* (2022) if the average incidence is between:
0 - 25%: then the incidence level is low;
25 - 50%: the incidence level is moderate;
50 - 75%: the incidence level is high;
75 - 100%: the incidence level is very high.

Incidence was used to determine the proportion of affected leaves on diseased plants, in order to assess disease severity.

Severity, or the severity index, was used to assess the degree of disease severity on the plants. The severity index of symptoms was evaluated using the COURS scale. This scale ranges from 0 (healthy plant) to 5 (plant severely affected by the disease). The severity levels of cassava mosaic disease according to the COURS scale are as follows (Innocent, 2012) :
Level 5: Leaves reduced to 1/10th of their original area, stunted shoots; the plant withers and dies within a few months;
Grade 4: Nearly all leaf blades curled, reduced vegetative growth.
Grade 3: Affected leaves deformed, partially curled, reduced vegetative growth.
Grade 2: Spot covering half the leaf blade, appearance of leaf deformities.
Grade 1: Yellowish spots covering 1/5 of the leaf blade.
Grade 0: No symptoms.
Using this COURS scale, the ACM severity index was calculated using the formula proposed by Moïse *et al.* (2022):

$$\text{Severity} = \frac{\sum n * b}{(\mathrm{N}-1)\,\mathrm{T}} \times 100. \qquad (4)$$

Where n = number of plants for each level of the COURS scale; b = level of the scale; N = number of levels in the scale used; and T = total number of plants evaluated across the entire field.

The figures below show the symptoms of viral diseases (ACM) observed in fields in Kalehe:

Figure 1. Symptoms of observed viral diseases (Source: Author)

2.4. Data processing techniques

Analysis of variance and correlation analysis using STATA software will be used for data processing.

- Analysis of variance

Data on disease incidence and severity were subjected to an analysis of variance (ANOVA) (Goumari, 2003) to determine whether or not there is a significant difference between cassava varieties, using Stata 13.0 software. Treatment means were separated using the least significant difference (LSD) and declared significant at a 95% confidence level (P = 0.05).

- Correlation Analysis

This technique allowed us to estimate the interdependence between incidence, severity, variables, groups, and locations. Mathematically, this is expressed as (Lobo Moa, 2012):

$$r = \frac{Cov_{xy}}{\sigma_X \sigma_Y} \text{ avec } Cov_{xy} = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{N}, \sigma_x = \sqrt{\frac{\sum (X - \bar{X})^2}{N}}, \ \sigma_y = \sqrt{\frac{\sum (Y - \bar{Y})^2}{N}}$$

Where: Cov(x,y) = covariance between x and y; σx and σy = standard deviation of x and standard deviation of y; N = number of observations.

3. Results

3.1. Incidence of African Cassava Mosaic in the Kalehe territory

In this section, we present the results of the incidence of African cassava mosaic (ACM) by group, locality and varieties identified in the fields in the Kalehe territory.

a) Incidence of ACM in cassava by group

The incidence of mosaic in the selected groups in the Kalehe territory. We note that the two groups Kalima (56.39%) and Mubugu (56.030%) have almost the same level of mosaic incidence (Table 1).

Table 1. Incidence of mosaic (%) by groups

Groups	Mean	Std. Dev.	Freq.
Kalima	56.3979	17.151023	100
Mubugu	56.0305	17.667524	100
Total	**56.2142**	**17.368363**	**200**
CV		**30.897**	

Source: Our analyses using Stata 13.0 software

Generally speaking, the incidence of ACM by group averaged 56.21%, with a CV (coefficient of variation) of 30.89%, showing a significant dispersion.

Table 2. ANOVA of incidence by grouping

Source	SS	df	MS	F	Prob > F
Between groups	6.749138	1	6.749138	0.02	**0.8815**
Within groups	60023.5973	198	303.149481		
Total	60030.3465	199	301.660033		
Bartlett's test for equal variances: chi2(1) = 0.0867 Prob>chi2 = 0.768					

Source: Our analyses using Stata 13.0 software

From this table we note that there is no significant difference between the mean values of mosaic incidence according to grouping, P-value being greater than 0.05, i.e. 0.8815 (p-value; at 5% significance level).

b) Incidence of cassava ACM by locality

Table 3. Incidence of mosaic (%) by locality

Localities	Mean	Std. Dev.	Freq.
Cigoma	55.831	17.400125	20
Irangi	55.832	16.679048	20
Kabare	55.9975	17.920357	20
Kashewe	56.8305	18.045649	20
Lukando	55.9975	17.952895	20
Mafuo	57.331	17.853295	20
Makuta	56.3305	17.930056	20
Makwe	55.9985	16.91289	20
Misima	55.997	17.920827	20
Mushunguti	55.9965	18.966662	20
Total	**56.2142**	**17.368363**	**200**
CV		**30.897**	

Source: Our analyses using Stata 13.0 software

This table provides information on the incidence of MAM in selected localities within the Kalehe territory. It can be seen that the localities of Mafuo (57.3%), Makuta (56.3%), and Kashewe (56.8%) have a high incidence of African cassava mosaic virus (ACMV), followed by MAKWE (55.99%), Mushunguti (55.99%), Lukando (55.99%), Kabare (55.9%), Misima (55.99%), Cigoma (55.8%), and Irangi (55.8%). Overall, the incidence of AMM across these locations averages 56.21%. This could contribute to lower yields due to leaf degradation and a reduction in leaf area, a phenomenon that would hinder tuber development by limiting photosynthesis.

Table 4. ANOVA of incidence by locality

Source	SS	df	MS	F	Prob > F
Between groups	43.370522	9	4.81894689	0.02	**1.0000**
Within groups	59986.9759	190	315.720926		
Total	60030.3465	199	301.660033		
Bartlett's test for equal variances: chi2(9) = 0.4355 Prob>chi2 = 1.000					

Source: Our analyses using Stata 13.0 software

From this table we can see that there is no significant difference between the mean values of mosaic incidence according to locality, P-value being greater than 0.05, i.e. 1.000 (p-value; at 5% significance level).

c) Incidence of cassava ACM by variety

Table 5. Incidence of mosaic by variety

Varieties	Mean	Std. Dev.	Freq.
Elona	39.0652	1.7890897	50
Namale	73.5298	2.553837	50
Nambiyomb	73.2634	2.6478105	50
Sawasawa	38.9984	1.815631	50
Total	**56.2142**	**17.368363**	**200**
CV		**30.897**	

Source: Our analyses using Stata 13.0 software

is table provides information on the incidence of African cassava mosaic virus (ACMV) by variety identified in the fields in Kalehe. These results show that all varieties identified in the Namale (73.5%), Nambiyo (72.26%), Sawasawa(38.99%), and Elona (39.06%) are susceptible to African cassava mosaic virus. This is because the susceptibility of cultivated cassava varieties to the virus depends both on environmental conditions and, above all, on their genetic makeup. The infection rate of newly introduced cassava varieties is significantly lower compared to that of locally grown varieties in the area (Kalondji, 2008). Generally speaking, the incidence of AMV across varieties averages 56.21%, with a CV (coefficient of variation) of 30.89%, indicating significant variation and, therefore, heterogeneity in our sample regarding mosaic incidence within the Kalehe territory.

Table 6. ANOVA of incidence by variety

Source	SS	df	MS	F	Prob > F
Between groups	59048.8597	3	19682.9532	3930.63	**0.0000**
Within groups	981.48674	196	5.00758541		
Total	60030.3465	199	301.660033		
Bartlett's test for equal variances: chi2(3) = 12.8695 Prob>chi2 = 0.005					

Source: Our analyses using Stata 13.0 software

The above table reveals a highly significant difference between the mean values of mosaic incidence and indicates a highly significant difference between varieties, P-value being less than 0.05 or 0.000 (p-value; at the 5% significance level). This significant difference observed between the varieties identified within each field indicates that the disease is not distributed in the same way across the whole field. Incidence varies from one grouping to another, and from one variety to another.

3.2. Severity of ACM in the Territory of Kalehe

In this section, we will present the results of the severity of ACM in cassava according to the groups, localities and varieties identified in the fields in the territory of Kalehe.

a) Severity of ACM in cassava according to groups

Table 7. Severity of mosaic (%) according to groups

Groups	Mean	Std. Dev.	Freq.
Kalima	2.5048	.54818798	100
Mubugu	2.5669	.47045152	100
Total	**2.53585**	**.51046562**	**200**
CV		**20.13**	

Source: Our analyses using Stata 13.0 software

This table shows the severity of mosaic according to the clusters selected in the Kalehe territory. It shows that the two clusters have a severity level of 2, with a CV (coefficient of variation) of 20.13%, showing a significant dispersion in terms of severity.

Table 8. ANOVA of mosaic severity by grouping

Source	SS	df	MS	F	Prob > F
Between groups	.1928205	1	.1928205	0.74	**0.3910**
Within groups	51.661635	198	.260917348		
Total	51.8544555	199	.260575153		
Bartlett's test for equal variances: chi2(1) = 2.2947 Prob>chi2 = 0.130					

Source: Our analyses using Stata 13.0 software

This table shows that there is no significant difference between the average mosaic severity values for the different groups, P-value being greater than 0.05, i.e. 0.3910 (p-value; at the 5% significance level).

b) Cassava ACM severity by locality

Table 9. Mosaic severity (%) by locality

Localities	Mean	Std. Dev.	Freq.
Cigoma	2.6175	.54419303	20
Irangi	2.522	.54356136	20
Kabare	2.6565	.33745604	20
Kashewe	2.464	.56779722	20
Lukando	2.47	.55577352	20
Mafuo	2.58	.63861693	20
Makuta	2.4235	.5368061	20
Makwe	2.488	.4708067	20
Misima	2.478	.51538029	20

Mushunguti	2.659	.37333349	20
Total	**2.53585**	**.51046562**	**200**
CV		**20.13**	

Source: Our analyses using Stata 13.0 software

This table provides information on the severity of ACM according to the localities selected in the Kalehe territory. It can be seen that all the localities identified in Kalehe have a severity level of 2, with a coefficient of variation of 20.13%, showing a significant dispersion in terms of severity.

Table 10. ANOVA of mosaic severity by locality

Source	SS	df	MS	F	Prob > F
Between groups	1.3257505	9	.147305611	0.55	**0.8334**
Within groups	50.528705	190	.265940553		
Total	51.8544555	199	.260575153		
Bartlett's test for equal variances: chi2(9) = 11.4588 Prob>chi2 = 0.246					

Source: Our analyses using Stata 13.0 software

This table shows that there is no significant difference between the mean values of mosaic severity according to group, P-value being greater than 0.05, i.e. 0.8334 (p-value; at the 5% significance level).

c) Cassava ACM severity by variety

Table 11. Mosaic severity (%) by variety

Varieties	Mean	Std. Dev.	Freq.
Elona	2.0916	.21050338	50
Namale	3.0192	.26777115	50
Nambiyomb	2.9768	.19100636	50
Sawasawa	2.0558	.1800577	50
Total	**2.53585**	**.51046562**	**200**
CV		**20.13**	

Source: Our analyses using Stata 13.0 software

The table shows that, on average, in the eco-climatic conditions of the Kalehe territory, the NAMALE variety was more severely attacked in both groups, and ranked first among the other varieties in terms of ACM severity (degree 3). NAMBIYO came second, followed by ELONA and SAWASAWA. This confirms that all the varieties identified in the Kalehe fields showed symptoms of African cassava mosaic disease (ACM) at different levels of severity.

The relatively high values for each level of severity can be explained in part by the fact that the appearance of symptoms is the result of the intensity of the plant's reaction to the attack of a virus, which can vary depending on the environment.

Generally speaking, the severity of African cassava mosaic is 2.53, a CV of 20.13% respectively, which shows a significant dispersion, and therefore, a heterogeneity of our sample in terms of mosaic severity in the Kalehe territory. Thus, the level and rate of attack on the crop by African cassava mosaic is high in the study area.

Table 12. ANOVA of mosaic severity by variety

Source	SS	df	MS	F	Prob > F
Between groups	42.7935095	3	14.2645032	308.56	**0.0000**
Within groups	9.060946	196	.046229316		
Total	51.8544555	199	.260575153		
Bartlett's test for equal variances: chi2(3) = 9.4764 Prob>chi2 = 0.024					

Source: Our analyses using Stata 13.0 software

Analysis of variance for mosaic severity indicates a highly significant difference between varieties, with P-value less than 0.05 or 0.000 (p-value; at the 5% significance level). This significant difference observed between the varieties identified within each field indicates that the disease is not distributed in the same way across the entire field. Severity varies from one variety to another.

3.3. Calculation of Correlation Coefficients

In this section, we show the relationship between incidence, severity, variants, groupings and localities.

Table 13. Correlation between incidence, severity, variety, groups and localities.

	Incidence	Severity	Variety	Group	Locality
Incidence	1.0000				
Severity	0.9101	1.0000			
Variety	**-0.0056***	**-0.0358***	1.0000		
Group	**-0.0106***	**0.0610***	0.0000	1.0000	
Locality	**-0.0102***	**0.0785***	0.0000	0.8704	1.0000

Source: Our analyses using Stata 13.0 software

As this table shows, the calculation of Spearman's correlation coefficients enables us to estimate the interdependence between incidence, severity, variants, groupings and localities.

The correlation coefficients between these variables are below 0.6, indicating a weak correlation. From these results, we deduce that there is a positive relationship between mosaic severity, grouping and locality. For all variables, their values are low, indicating a weak positive correlation. In short, the higher the severity of cassava mosaic disease, the more disease cases occur in groups and localities.

Furthermore, we note that there is a negative relationship between mosaic incidence, variety, group and locality, as well as a negative relationship between mosaic severity and variety. For all variables, their values are low, indicating a weak positive correlation. And it can be said that the lower the level of incidence of cassava mosaic, the more unaffected the varieties, and the more unaffected the groups and localities. Also, the lower the level of mosaic severity, the fewer the varieties affected.

4. Discussion

The study shows that the level of attack on the crop by African cassava mosaic is high in the Kalehe territory. ACM was present in both the groups mentioned above. The highest incidence of ACM was 56.39% in Kalima and 56.030% in Mubugu. By locality, the highest incidence of ACM was 57.3% in Mafuo, Makuta (56.3%), and Kashiewe (56.8%), followed by Makwe (55.99%), Mushunguti (55.99%), Lukando (55.99%), Kabare (55.9%), Misima (55.99%), Cigoma (55. 8%), and Irangi (55.8%), with an overall average for these 10 localities of 56.21%. In addition, all the varieties identified in the fields at Kalehe, notably Namale, Nambiyo, Elona, and Sawasawa, were susceptible to African cassava mosaic, with relative incidences of 73.5%, 72.26%, 38.99% and 39.06%, respectively, and a high severity level ranging from 2 to 3. There was a negative relationship between mosaic severity and variety, i.e., the lower the level of mosaic severity, the less diseased the varieties.

These results seem to agree with those found by Kabemba et *al*., (2017) who find 70.23% of cassava plants analyzed have a symptom severity index (SSI) ranging from 2 to 5 respectively in Kimwenza and Mitendi. In the home gardens, 52.5% of plants had a severity index in the same range. Four cassava cultivars were identified in the fields. Of these, Nsanginsangi was the most sensitive, with an incidence of 81.7%, while Mankanu was the least sensitive, with an incidence of 52.8%. These results almost coincide with those found in our work at the differences of the research field. In the same vein, these results go hand in hand with those found by Bulonza et *al*., (2023) who also found incidences ranging from 46 to 65.5% and moderate severities varying from level 2 in 2020 to level 2.6 in 2022, and ACM disease is widespread in the territories surveyed. These results also corroborate those found by Henry et *al*., (2021), who found that the severity and incidence of mosaic were higher on the local variety than on the improved varieties, one of which proved to be somewhat susceptible to the disease. Also Moïse *et al.,* (2022) found an average incidence of African cassava mosaic of 39.52% in monoculture, 22.36% in crop associations and 12.10% in agroforestry systems. Severity values respectively 20.79% for monoculture, 10.4% for association and 5.73% for agroforestry systems.

The results reported by Bulonza et *al*. (2024) are similar to ours but differ from the research objective and field. They found that the various virus strains (African Cassava Mosaic Virus (ACMV), East African Cassava Mosaic Virus (EACMV), ACMV+EACMV-UG, EACMCV, and unspecified strains) were widespread in South Kivu. The EACMV-UG strain was widespread in all territories of South Kivu province, while the Cameroon strain (EACMCV) was found only in Kalehe territory (2%).

5. Conclusion

The plant health crisis caused by African cassava mosaic virus is a serious problem, with farmers in the Kalehe region, in general, and in the two farming groups (Mubugu and Kalima) in particular, suffering severe consequences. This disease has a massive impact on the physiological functioning of the plants, particularly photosynthesis, the primary process for producing organic matter, due to severe damage to the leaves. Thus, this study has demonstrated the extent of African cassava mosaic virus infection in Kalehe. Thus, the level of African cassava mosaic virus infestation is high in the Kalehe territory. We recommend that future researchers intensify studies on the mechanisms of spread and evolution of this disease in the region by assessing actual yield losses.

6. Reference

Alimasi, A. (2011). Study on the incidence and severity of African cassava mosaic disease in Bunia DRC [Unpublished manuscript].

Bokanga, M., & Otoo, E. (1994). Cassava based foods: How safe are they? In F. Ofon & S. K. Hahn (Eds.), Tropical root crops in developing economies (pp. 225–234). Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, October 20–26, 1991, Accra, Ghana. https://doi.org/10.17660/ActaHortic.1994.380.35

Bugandwa, M. A. (2019). Survey theory and practice. Université Catholique de Bukavu.

Bulonza, J.-C., Yasenge, S., Empata, L., Likiti, O., Muhindo, H., & Dowiya, B. (2023). Evolution des paramètres épidémiques associés à la mosaïque africaine du manioc au Sud-Kivu en République Démocratique du Congo. *Agronomie Africaine*, 35(3), 441–451.

Bulonza, J.C., Ugencan, P., Muvirirwa, R., Empata, L., Bakelana, T., Muhindo, H., Dowiya, B., & Monde. G. (2024). Incidence moléculaire et distribution des virus associés à la mosaïque africaine du manioc au Sud-Kivu en République Démocratique du Congo. *African Crop Science Journal*, 32(3), 193–206. https://doi.org/10.4314/acsj.v32i3.1

Chidumayo, E., Okali, D., Kowero, G., & Larwanou, M. (Eds.). (2011). Forests, wildlife and climate change in Africa. African Forest Forum.
Déogracias. (2009). Context analysis of Kalehe Territory (pp. 1–54).
Deuwel, A. (2022). Different sampling methods [Unpublished manuscript].
Donald, L. P. (1998). Global cassava production strategy: Processing a traditional tropical root crop—Launching rural industrial development and increasing incomes for poorer farmers.
Dumat, C., & Maris, S. (2016). Cassava cultivation worldwide: Socio-scientific analysis of environmental opportunities and risks, to promote ecological transition.
FAOSTAT. (2007). FAOSTAT yearbook 2006. Food and Agriculture Organization of the United Nations.
FAOSTAT. (2023). Food and agriculture data. http://www.fao.org/faostat/en/#data
Faugère, E. (1989). Socio-economic analysis of production systems in Maré, Loyalty Islands Province.
Fauquet, C., & Fargette, D. (1990). African cassava mosaic virus: Etiology, epidemiology, and control. Plant Disease, 74(6), 404–411. https://doi.org/10.1094/PD-74-0404
Food and Agriculture Organization of the United Nations. (2018). Guidelines on measuring post-production losses: Recommendations on the design of a statistical system for calculating harvest and post-harvest losses of food grains (cereals and pulses).
Ganza, D. N., & Cirezi, P. (2019). Influence of farmer characteristics on adoption of improved cassava varieties in Kabare, South Kivu province in eastern DR Congo. International Journal of Innovation and Applied Studies, 27(1), 43–53. http://www.ijias.issr-journals.org
Goumari, A. (2003). Vérification des conditions d'application de l'analyse dela variance sur les résultats d'une expérience en champ. *Actes de l'Institut Agronomique et Vétérinaire Hassan II (Maroc)*, 23 (2-4), 101-107.
Guthrie, J. (1999). Controlling African cassava mosaic.
Henry, U. U., Wa, M., Romain, M., Eric, M. M., & Clerisse, C. (2021). Evaluation of the impact of cassava mosaic disease on the yield of fresh cassava roots in the East of Democratic Republic of Congo. Journal of Applied Biosciences, 34(1), 32–37.
Hounkponou, S. K., Sagbo, R. R. S., Nago, S. G. A., Hounkpè, I. A., & Yabi, J. A. (2020). Vulnérabilité de la culture de maïs dans la commune de Dangbo face aux changements climatiques. Revue des sciences humaines et des civilisations africaines, 96–111.
Innocent, Z. (2012). Epidemiology of cassava mosaic disease in the Central African Republic, varietal resistance and thermotherapy sanitation [Doctoral dissertation].
Janssens. (2001). Cassava in agriculture in tropical Africa.
Kabemba, N. K., Gikung, J. M., & Otono, F. B. (2017). Incidence et sévérité de la mosaïque africaine du manioc dans les champs et les jardins de case à Kinshasa (République Démocratique du Congo). *Tropicultura*, 35(3), 173-179. https://doi.org/10.25518/2295-8010.1246.
Kalondji. (2008). Behavior of cassava against African cassava mosaic under conditions of natural infestation at Gandajika.
Katunga, M. M. D., Balemirwe, K. F., Masheka, F., & Zamukulu, P. (2020). Production systems and contribution on characterization of local chickens in smallholder farmer in Sud-Kivu Province, Democratic Republic of the Congo (DRC). *Open Access Library Journal*, 7(3), e6171. https://doi.org/10.4236/oalib.1106171
Legg, J. P., Kumar, P. L., Makeshkumar, T., Tripathi, L., Ferguson, M., Ismail, A. M., & Ling, K. S. (2015). Cassava virus diseases: Biology, epidemiology, and management. *Advances in Virus Research*, 91, 85–142. https://doi.org/10.1016/bs.aivir.2014.10.001
Lobo Moa. (2012). The impact of introducing a financial messaging service on a bank's profitability: The case of Western Union International at the International Credit Bank, 2007–2011 [Master's thesis].

Mahungu, N. T. (2014). Planting material multiplication and disease and pest management: Training manual for field agents (p. 44). International Institute of Tropical Agriculture.
Moïse, M. K., Eloge, K. M., Moïse, K. K., Florence, K. M., & Kanyere, P. (2022). Influence of cropping systems on the incidence and severity of African cassava mosaic in the locality of Kivira (North-Kivu, DR Congo). *International Journal of Innovation and Applied Studies*, 36(2), 435–448.
Monde. (2011). Specialized plant pathology [Unpublished course].
Mouketou, A., Mavoungou, J. F., Lepengué, A. N., Mintsa, R., & Ndong, A. M. (2022). Cassava mosaic disease incidence and severity and whitefly vector distribution in Gabon. *African Crop Science Journal*, 30(2), 167–183. https://doi.org/10.4314/acsj.v30i2.5
Munyuli, T., Cihire, K., Rubabura, D., Mitima, K., Kalimba, Y., Tchombe, N., Mulangane, E. K., Birhashwira, O., Umoja, M., Cinyabuguma, E., Mukadi, T. T., Ilunga, M. T. & Mukendi, R. T. (2017). Farmers' perceptions, believes, knowledge and management practices of potato pests in South-Kivu Province, eastern Democratic Republic of Congo. *Open Agriculture*, 2, 362–385. https://doi.org/10.1515/opag-2017-0040
Ntawuruhunga, P., Okuja, O., Legg, J., & Obambi, M. (2002). Situation of the viral pandemic disease cassava mosaic in the Democratic Republic of Congo.
Nweke, F. I. (1996). A cash crop in Africa (COSCA Working Paper No. 14). Collaborative Study of Cassava in Africa, International Institute of Tropical Agriculture.
Patil, B.L., & Fauquet, C. M. (2009), Cassava mosaic geminiviruses: actual knowledge and perspectives. *Molecular Plant Pathology*, 10: 685-701. https://doi.org/10.1111/j.1364-3703.2009.00559.x
Reny-Nolin, E. (2012). Week 13 report: Compléments sur l'échantillonnage aléatoire simple et stratifié (p. 8). FSG - Département de mathématiques et de statistique, Université de Laval.
Silvestre, P., & Amoussou, M. (1983). Cassava. Maisonneuve et Larose and A.C.C.T.
Thomas, I. U., Akata, O. R., Udounang, P. I., & Ben, F. E. (2025a). Economic Analysis and Response of Cassava (Manihot esculenta Crantz) to Different Tillage Practices in Coastal Plain Soil of Akwa Ibom. Open Soil Science and Environment, 3(1), 29–36. https://doi.org/10.70110/osse.v3i1.48
Thomas, I. U., Akata, O. R., Udounang, P. I., & Ben, F. E. (2025b). Response of Cassava (Manihot esculenta Crantz) to Different Soil Amendments in Rainforest Ecology of Southern Nigeria. *Open Soil Science and Environment*, 3(2), 48–55. https://doi.org/10.70110/osse.v3i2.49
United Nations. (2023). United Nations advocacy for Kalehe: One of the greatest natural disasters in the history of the Democratic Republic of Congo (DRC) deserves greater attention and solidarity (pp. 77–78).
WAVE. (2020). Report on epidemiological surveillance of African cassava mosaic virus in South Kivu. www.wave-center.org
Williams, T. O., Mul, M., & Cofie, O. (2014). Reference document: Climate-smart agriculture in the African context.