Original Research Article

Occurrence, distribution and farmers' perceptions of cassava diseases in Gabon (Central Africa).

ABSTRACT

Aims: In order to identify and assess the level of cassava diseases in farms present in Gabon, disease surveys were carried out across the country in 2021 and 2022.

Methodology: The method used is based on administration of questionnaire to cassava growers, supplemented by the recognition of disease symptoms on 30 randomly selected plants in farms.

Results: Some 201 cassava growers were interviewed, 84.04% (n=169) of them were women and 15.92% (n=32) men. Nearly 65.41% of the farmers interviewed had a primary school education and were aged between 51 and 55. The majority of these producers had farming as their main activity (89.73%). The results showed the occurrence of five cassava diseases in the study area: cassava mosaic (Im = 60.22%; Sm = 2.95), anthracnose (Im = 19.45%; Sm = 3), leaf necrosis (Im= 9.95%; Sm = 2.71), bacteriosis (Im = <1%; Sm = 3), and root rot (Im = <1%; Sm = 2.61). Among these diseases, mosaic was the most frequently observed in the provinces surveyed. Its incidence was lowest in Estuaire (38.40%) and highest in Ogooué-Ivindo (71.36%) and Ogooué-Maritime (71.76%). Anthracnose incidence was lowest in Moyen-Ogooué (4.05%) and highest in Haut-Ogooué (36.50%). For leaf necrosis, Woleu-Ntem (0.71%) and Ogooué-Ivindo (31.11%) recorded the lowest and highest incidence respectively.

Conclusion:In order to control these cassava diseases, it is important to initiate and implement awareness campaigns and training workshops for growers to encourage them to adopt good farming practices.

Keywords: Cassava, diseases, fields, farmers, socio-demography, Gabon.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the main food crop for almost 98% of farmers in Gabon and it ranks secondin terms of production [1]. It is grown in nine provinces of the country and consumed by 80% of the population[2]. Cassavais an important crop in the Gabonese diet and consumed by all peoplein various preparations such as a porridge, side dish or dessert[3]. It is considered as an important source of carbohydrates for the nutritional and food security of populations of Gabon and Central Africa in general. Through its food importance, cassava is very requested by populations. But its local production is not enough. Indeed, the cassava production in Gabon remains yet insufficient, because of several reasons, namelythe lack of technical knowledge by farmers to

manage larger fields, the pests and diseases[4–7]. Indeed, cassava plants are subjected to pests and diseases at all stages of their vegetative cycle and on roots, leaves and stems. Among them, the most damageable are: cassava mealybug, cassava green mite, African cassava mosaic diseases, cassava brown streak disease, cassava bacterial blight and cassava anthracnose [5, 8, 9]. All these pests and diseases contribute to yields losses of cassava in Africa[10, 11].

In Gabon, a few investigations have been carried out to characterize cassava viral diseases [7, 12, 13]. These studies confirmed the presence of cassava mosaic diseasesspecies caused by the following Begomovirus species: *African cassava mosaic virus*, *East African cassava mosaic virus* and *East African cassava mosaic virus* Ugandan strain[7, 12, 13].

The spread of cassava Begomovirus species is probably facilitated by informal exchanges of plant material between farmers [13].More recently,Mouketou*et al.*[7] conducted a nationwide epidemiological survey to assess the cassava mosaic disease situation, its incidence, severity and vector abundance. While the epidemiology of cassava viral disease is beginning to be well documented in Gabon, it is not the case of the others such as bacterial and fungi diseases.Mouketou*et al.*[7] have shown that multi-diseases co-infections reduce agricultural productivity, considerably.This observation highlights the effect of multi-pathogens infections on the growth and productivity of virus-infected cassava plants, and justifies the relevance of conducting generalized epidemiological studies for a global assessment of disease symptom observations in order to propose effective phytosanitary surveillance and response actions. The aim of this study is to define the typology of cassava growers, their perception of the disease and assess the incidence, severity and distribution of the diseases identified in agricultural fields in Gabon.

2. MATERIALS AND METHODS

2.1 Study area and sampling plan

Disease epidemiological study was carried out in Gabon (Figure 1) over two seasons, from November to December 2021 (short rainy season) and from February to April 2022 (long rainy season). This Congo Basin country is located in West Central Africa, straddling the equator between latitudes 2°30' North and 3°55' South, and between longitudes 10° West and 14° East.

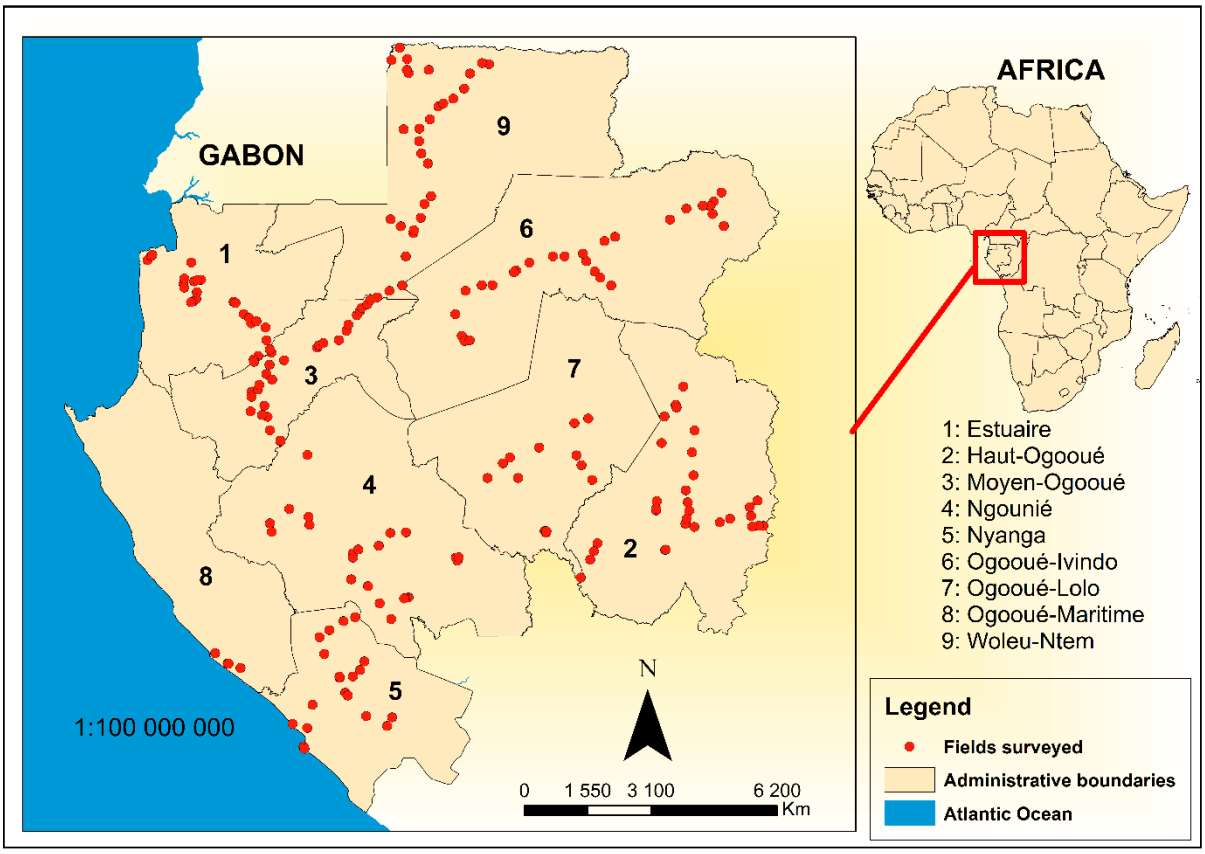

Figure 1: Map showing the various cassava fields surveyed in the study area.

It covers an area of 267,667 km² and has a population of around 1,811,079 inhabitants. It is bordered to the north by Equatorial Guinea and Cameroon, to the east and south by the Republic of Congo and to the west by the Atlantic Ocean[14].

Climatically, Gabon enjoys a hot, humid equatorial climate, with two distinct seasons: a rainy season from September to May and a dry season from June to August [15]. The mean temperatures range from 21° to 32°C [15]. Monthly rainfall ranges from 1400 mm to 380 mm [16]. Gabon's topography is characterized by lowlands on the coast, grassy and wooded savannahs in the south and east, and hills in the interior. Around 85% of the country's surface area is covered by forest, a potential source of arable land [17]. Administratively, Gabon is divided into provinces, departments, cantons and villages[14].

Epidemiological surveys were carried out in 201 cassava fields (Figure 1) covering as wide a range of edapho-climatic conditions and cropping practices as possible [18]. These fields were distributed across Gabon's nine administrative provinces [17]. They were selected on the basis of their accessibility, the intensity of cassava cultivation, the age of the plantation (3 to 6 months) and the distance between fields (5 to 20 km) using the harmonized protocol of WAVE network [7].

2.2 Involvementof cassava growers and achievement of the questionnaire

In order to identify the socio-demographic characteristics of cassava growers, the farmers to be surveyed were included in the study after obtaining their verbal consent. Subsequently, questionnaire interviews were administered individually or via focus groups with cassava growers. To this end, pre-formulated questionnaires were administered in the fields to the various respondents [19]. All the questions asked were aimed at establishing a typology of the cassava growers encountered. These questions concerned the following aspects: gender, age, profession, level of education, methods of acquiring cuttings and techniques for preserving cuttings, information about cassava diseases. All exchanges were conducted in French or in the vernacular language where it was necessary, by using the services of an interpreter for quality and effective delivery.

2.3 Collection of agro-epidemiological data from cassava fields

Agronomic and epidemiological data were collected by visual observation of disease symptoms in the field. The agronomic and epidemiological characteristics of each field were recorded and coded on collection sheets for subsequent analysis. Thesewere as follows:

a) *General information on fields*: geographical coordinates of cassava fields were collected using a Garmin GPSmap 64X device, along with the parameters summarized in Table 1.

Table 1Characteristics of surveyedfields

Designation	**Features**
Cropping areas	☞ ZCF = Zone of ForestCultivation; ☞ ZCS = Zone of Savannah Cultivation ; ☞ ZCP = Zone of Dale Cultivation.
Croppingsystems	✓ Monoculture = Cassavaonly; ✓ Polyculture = Cassava cultivation combined with other crops.
Grass cover levels	▪ Clean = Weed-free plot ; ▪ Little weed cover = Less than 25% weed cover ; ▪ Grassed = 50% Weed cover ; ▪ Very weedy = Over 75% weed cover.
Planting modes	☞ Flat = planting without pseudo ploughing just a hole; ☞ Mound = ploughing and the soil is brought back around the plant; ☞ Billon = ploughing with raising of the soil along the plantation lines.
Soil types	1= Clayey ; 2= Sandy ; 3= Sandy-clay.

b) *Data on cassava diseases*: these were collected on 30 cassava plants taken randomly by walking in the field on two diagonals [20]. The characteristic symptoms of each disease were observed that is the leaves, stems and roots (whereit was possible),for visual identification of the characteristic symptoms of each disease. In addition, three (3) epidemiological parameters were assessed, namely: type of symptoms, mean incidence (I_m) and mean severity (S_m).

2.3. Assessment of disease incidence

The mean incidence (I_m) of each disease was calculated by multiplying the number of symptomatic plants by 100 and divided by total number of plants [21].

$$(1)\text{Mean incidence } (\%) = \frac{Total\ number\ of\ plants\ infected}{Total\ number\ of\ plants\ observed} \times 100$$

The meanincidences were calculated by province, then classified by level on a scale ranging from low to very high, as shown in the table below**.**

Table 2 Scale classes for mean incidence level

I_m (%)	**Levelscale**
[0-25]	Low
[26-50]	Medium
[51-75]	High
[76-100]	Very high

2.4. Determiningof diseaseseverity

On each plant observed, an overall symptom severity score was assigned according to a rating scale corresponding to each type of disease:

- For cassava mosaic disease, symptom observations were made on the foliage of young plants with at least 5 leaves. A scale of 1 to 5 was used to assess severity, i.e.: 1 = no symptoms; 2 = light chlorotic patterns and slight distortion of leaf base only; 3 = mosaic patterns on all leaves and leaf distortion; 4 = mosaic patterns on all leaves, leaf distortion and general reduction in leaf size; 5 = twisted/shapeless leaves and stunting of whole plant [22]. The meanseveritywasthencalculated by province.
- For cassava bacterial blight (cassava fire blight), the level of disease severity was estimated on a scale of 1 to 5, with 1 = no symptoms; 2 = only angular leaf spots ; 3 = angular leaf spots, wilting, scorch, defoliation and sometimes exudates on stems/petioles; 4 = leaf scorch, wilting,

defoliation, exudates and tip dieback; 5 = leaf scorch, wilting, defoliation, exudates, dieback and stunted plants [23].

- For cassava anthracnose, observations were made on the main stem, petioles and apex of plants. The severity of the disease was assessed based on scale of 1 to 5, using the method ofIkotun and Hahn [24], where 1 = no symptoms; 2 = development of shallow cankers lower down the stem; 3 = development of successive cankers higher up the plant, with the earliest cankers becoming larger and deeper; 4 = development of dark-brown lesions on green shoots, petioles and leaves. Young shoots collapse and are deformed; 5 = wilting and drying of shoots and young leaves, and death of part or all of the plant.
- For leaf necrosis, a severity score was given, namely: 1 = no symptoms; 2 = severity between 1% and 25% of the leaf area; 3 = severity between 25% and 50% of the leaf area; 4 = severity between 50% and 75% of the leaf area; 5 = severity between 75% and 100% of the leaf area[25].
- To assess root rot, a severity score was used[26]. Detailed inspection of the roots by digging was not possible in the farmers' fields due to the age of the fields visited, on the one hand, and the farmers' refusal, on the other. However, when responding to the questionnaire, growers systematically reported the presence or absence of rot in fields harvested in 2022 and for accessions older than 12 months after planting (MAP).

After observations, an mean severity (S_m) for each disease was calculated for diseased plants only [20]. We used the formula shown below:

$$(2)\ \text{Mean of severity} = \frac{\sum_2^5 \quad \text{Score of severity of plants}}{\sum \quad \text{Plants infected}}$$

2.5. Data analysis

The data obtained was entered into Microsoft Excel 2016. The results were presented in the form of Tables and Figures. The statistical analyses were performed using Python 3.10.6 software. The numerical data were expressed as mean, standard deviation, minimum and maximum. Categorical data, on the other hand, were expressed as frequencies. Various statistical tests were applied to data with and without a normal distribution (Shapiro-Wilk test). The differences within the same group were evaluated using Pearson's Chi^2 test. In addition, differences between two groups were estimated using the Mann-Whitney U test. On the other hand, differences within several groups were assessed using the non-parametric Kruskal-Wallis test and the Tukey test for multiple pairwise comparison of means. The association between incidence and severity was assessed usingPearson's correlation analysis. The significancethreshold for all tests was set at 0.05.

3. RESULTS

3.1. Socio-demographic profile of cassava farmers

The majority of cassava farmers interviewed were women (n=169; 84.04%). The men represented 15.92% (n=32) of the total. These farmers were mostly between 51 and 55 years old (35.33%) and have a primary school education (65.41%). The majority of these cassava growers practice agriculture as their main activity (89.73%) (Table 3).

Table 3 Summary of farmers' socio-demographic characteristics

Parameters	Modalities	Number (n)	Percentage (%)	P-value
Type	Female	169	84.08	9.36×10^{-12}
	Male	32	15.92	
Age	26-30	3	1.49	1.79×10^{-16}
	31-35	12	5.97	
	36-40	3	1.49	
	41-45	48	23.88	
	46-50	25	12.44	
	51-55	69	34.33	
	56-60	18	8.96	
	61-65	21	10.45	
	66-70	2	1	
Educationallevel	None	11	5.47	9.32×10^{-40}
	Primary	131	65.17	
	Professional	5	2.49	
	Secondary	49	24.38	
	Superior	1	0.5	
	University	4	1.99	
Otheractivities	Employee	18	8.96	8.65×10^{-32}
	Retirement	3	1.49	
	No other employment apart from farming	180	89.55	

3.2 Farmers' preferred agronomic practices for cassava

The analysis of the agronomic characteristics summarized in Table 4 shows that the majority of farmers interviewed prefer mixed cropping (86.57%) as their cropping system. Nearly 69.15% of these farmers also prefer the flat cultivation method. They acquire cassava cuttings most often through self-production (82.09%), and frequently store them in damp locations (97.51%). These farmers prefer to grow their cassava on clay soils (84.08%).

Table 4. Agronomic characteristics of cassava farms visited

Parameters	Modalities	Number (n)	Percentage (%)	P
Cropping system	Polyculture	174	86.57	2.59×10^{-13}
	Monoculture	27	13.43	
Growing methods	Flat	139	69.15	1.06×10^{-22}
	Mound	27	13.43	
	Ploughing	24	11.94	
	Ploughing on ridge	11	5.47	
Acquiringcuttings	Self-production	165	82.09	4.10×10^{-24}
	Purchase	25	12.44	
	Exchange betweenfarmers	11	5.47	
Techniques for preservingcuttings	Damp area	196	97.51	5.58×10^{-41}
	In situ	4	1.99	
	No conservation	1	0.5	
Soil type	Clay	169	84.08	2.67×10^{-40}
	Sandy	15	7.46	
	Sandy-clay	14	6.97	
	Clay-sandy	3	1.49	

3.3. Symptomatic diagnosis of cassava diseases and incidence

A total of five (5) cassava diseases were identified in all the cassava plantations surveyed: (1) cassava mosaic (viral disease), (2) bacteriosis (bacterial disease), (3) anthracnose, (4) leaf necrosis and (5) root rot (fungal diseases) (Figure 2).

Cassava mosaic [I_m= 66.8%] was the most frequently observed disease during epidemiological surveys, followed by anthracnose (I_m= 21.2%) and leaf necrosis (I_m = 11.7%). Bacteriosis and root rot, were rarely observed, with incidences of less than 1% (I_m = 0.1-0.3%).

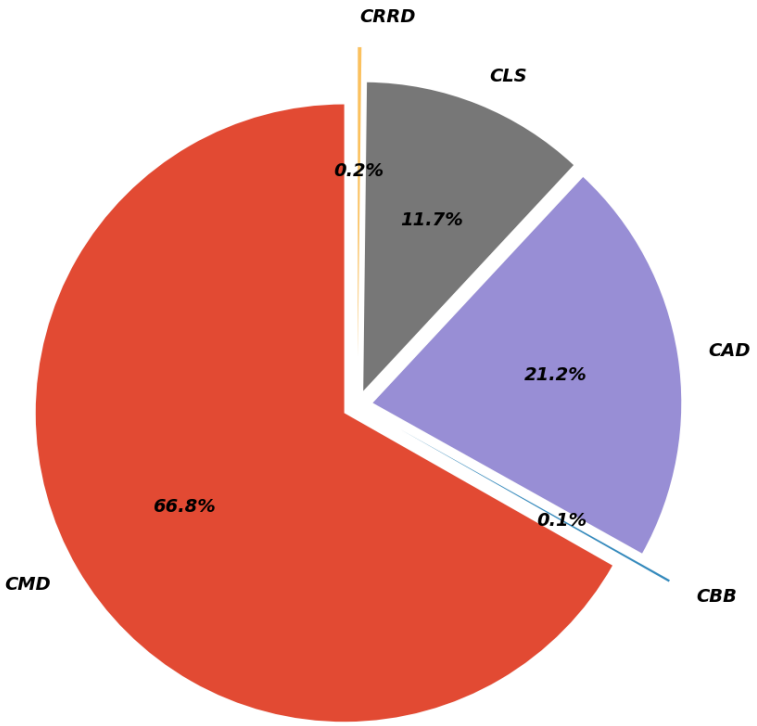

Figure 2. Incidences of cassava diseases identified in the surveyed farms.

CMD= *Cassava Mosaic Disease ;****CBB***= *Cassava Bacterial Blight ;* ***CAD***= *Cassava Anthracnose Disease ;* ***CLS***= *Cassava Leaf Spot ;* ***CRRD***= *Cassava Root Rot Disease*.

3.4. Distribution of cassava diseases by province

Cassava mosaic was the most common disease in all the fields surveyed, with a relatively high mean incidence (I_m = 60.22%), with intra-regional values varying from38.4% to 71.76%. The Estuaire province showed the lowest incidence of cassava mosaic (I_m = 38.4%), compared with double that for fields in Ogooué-Ivindo(I_m =71.36%) and Ogooué-Maritime (I_m =71.76%) (Figure 3).

Anthracnose was the second most frequently observed disease after cassava mosaic (I_m = 19.45%), with disparate incidence values between provinces, more specifically between Moyen-Ogooué(I_m = 4.05%) and Haut-Ogooué(I_m = 36.50%) (Figure 3). Leaf necrosis showed a low mean incidence (I_m =9.95%), with insignificant values in Woleu-Ntem(I_m = 0.71%) and remarkable values in Ogooué-Ivindo (I_m = 31.11%) (Figure 3).

Finally, bacterial blight and root rot were very rarely observed in this study, with similar and insignificant mean incidences (I_m = 0.5%) (Figure 3).

Furthermore, the result of the Tukey test's multiple comparison of two-by-two means (Table 5) shows that in all the provinces surveyed, the mean incidence of cassava mosaic was statistically different from that of other cassava diseases ($p < 0.001$). Similarly, the mean incidence (I_m) of anthracnose was significantly different from that of bacterial blight ($p = 0$), leaf necrosis ($p = 0.032$) and root rot ($p = 0$). On the other hand, no significant difference was observed between the mean

incidence of bacteriosis and that of leaf necrosis (p = 0.0514). No significant difference was found between the incidence of bacteriosis and that of root rot (p = 1).

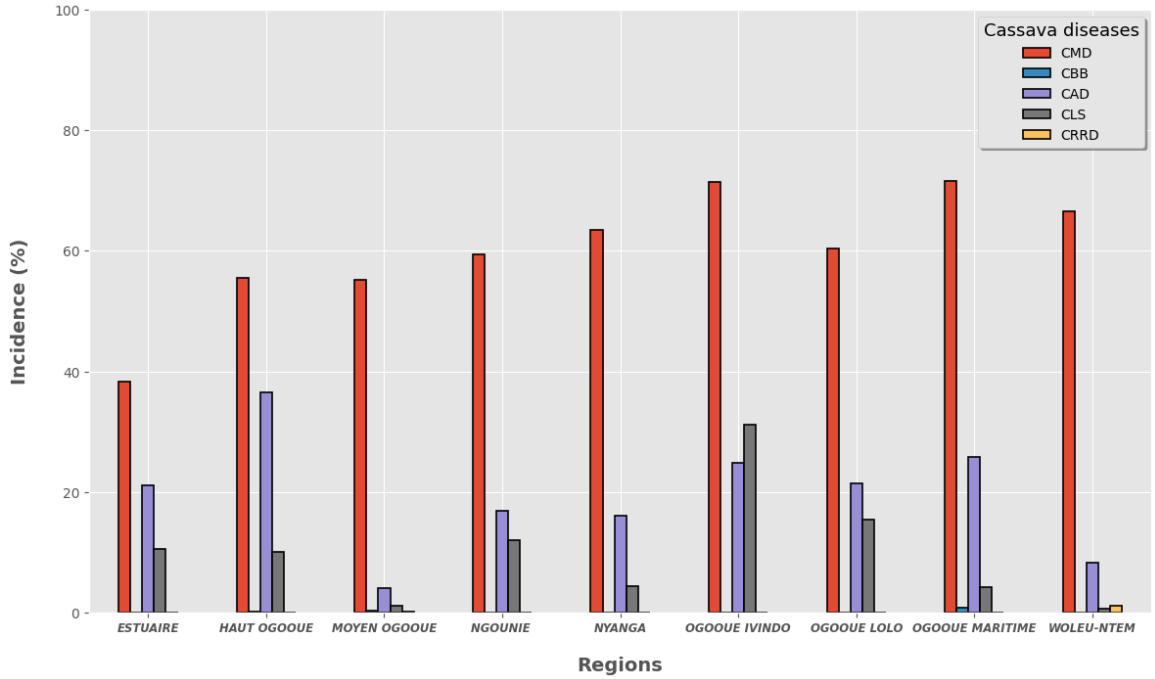

Figure 3. Distribution of cassava diseases by province surveyed

***CMD**= Cassava Mosaic Disease ;**CBB**= Cassava Bacterial Blight ; **CAD**= Cassava Anthracnose Disease ; **CLS**= Cassava Leaf Spot ; **CRRD**= Cassava Root Rot Disease.*

Table 5. Results of Tukey's multiple comparison tests

Group 1	Group 2	Mean diff.	P	Lower	Superior	Reject
Anthracnose	Bacteriosis	-18.9556	0.0	-28.1658	-9.7453	True
Anthracnose	Mosaic	42.6933	0.0	33.4831	51.9036	True
Anthracnose	Leafnecrosis	-9.7822	0.0325	-18.9924	-0.572	True
Anthracnose	Root rot	-18.9833	0.0	-28.1936	-9.7731	True
Bacteriosis	Mosaic	61.6489	0.0	52.4387	70.8591	True
Bacteriosis	Leafnecrosis	9.1733	0.0514	-0.0369	18.3836	False
Bacteriosis	Root rot	-0.0278	1.0	-9.238	9.1824	False
Mosaic	Leafnecrosis	-52.4756	0.0	-61.6858	-43.2653	True
Mosaic	Root rot	-61.6767	0.0	-70.8869	-52.4664	True

3.5. Distribution of cassava diseases according to agronomic variables

The incidence of cassava diseases varied according to agro-ecological zone, cropping method, cropping system or level of weed cover (Figure 4). According to agro-ecological zone (Figure

4A), the incidence of different cassava diseases was higher in the forest zone (mosaic: I_m = 65%; anthracnose: I_m = 20%; leaf necrosis: I_m = 15%) and the savannah zone (mosaic: I_m = 60%; anthracnose and leaf necrosis: I_m = 5%) than in the highland zone (mosaic and anthracnose: I_m = 18%). As for cultivation methods, the incidence of cassava diseases was higher in fields with seed hole (mosaic: I_m = 72%; anthracnose: I_m = 50%; leaf necrosis: I_m = 18%) than in fields with other types of cultivation techniques (Figure 4B). In addition, the incidence of the identified diseases were higher in fields with polyculture (mosaic: I_m = 62%; anthracnose: I_m = 19%; leaf necrosis: I_m = 15%) than those with monoculture (mosaic: I_m = 44%; anthracnose: I_m = 18%; leaf necrosis: I_m = 3%) (Figure 4C). Finally, regarding to grass levels, we recorded the highest incidences in fields where grass level was mean (mosaic: I_m = 79%, anthracnose: I_m = 25%; leaf necrosis: I_m = 18%) than in cassava fields with high or low grass levels (Figure 4D).We could note that cassava mosaic was predominant in all biotopes studied (ecology, cultivation, grass level, cultivation system) comparatively to other diseasesidentified ($p < 0.001$). But, there was no significant difference between mosaic and anthracnose in the cultivated zones of the high dales ($p = 0.90$) (Figure 4).

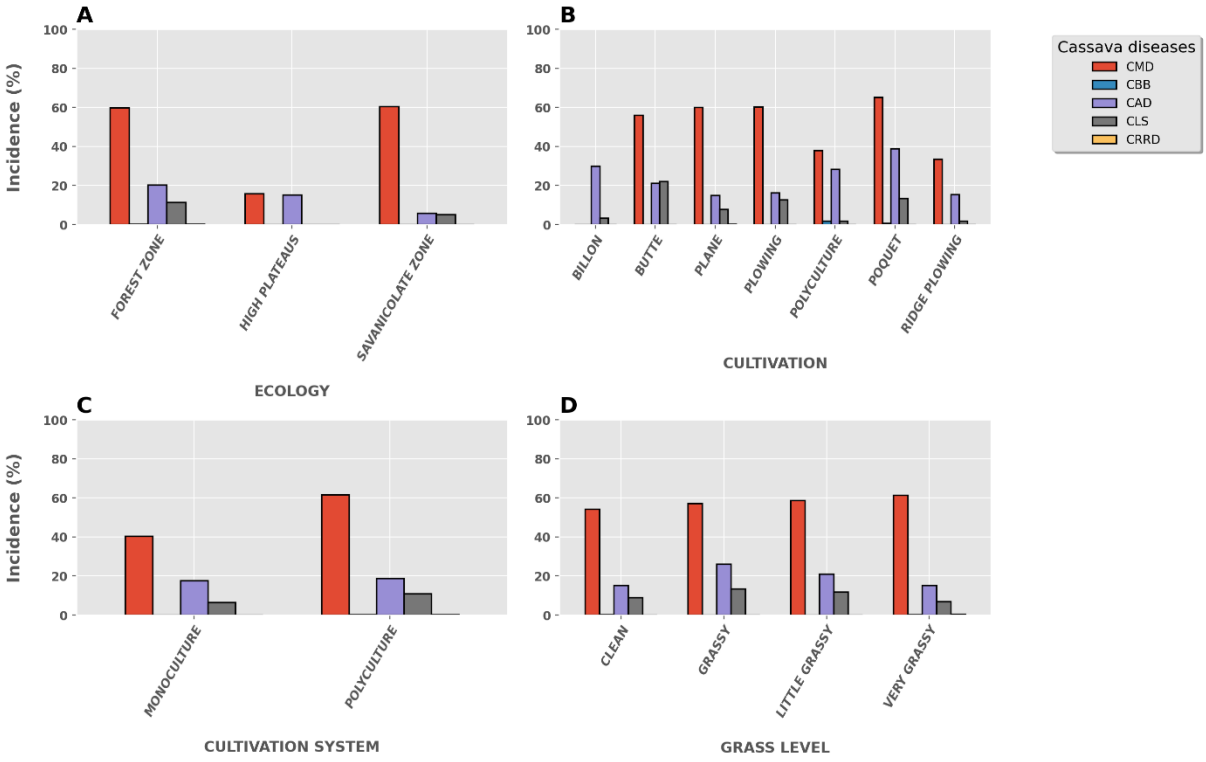

Figure 4: Distribution of cassava diseases according to agronomic parameters.

A) *Incidence of cassava diseases according to ecology,* ***B)*** *Incidence of cassava diseases according to cropping method,* ***C)*** *Incidence of cassava diseases according to cropping system,* ***D)*** *Incidence of cassava diseases according to grass level.*

CMD*= Cassava Mosaic Disease ;****CBB****= Cassava Bacterial Blight ;* ***CAD****= Cassava Anthracnose Disease ;* ***CLS****= Cassava Leaf Spot ;* ***CRRD****= Cassava Root Rot Disease*.

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3.6. Severity levels of cassava disease according to the surveyedprovinces

3.6.1. Severity levels of viral disease according to provinces (regions*)*

For cassava mosaic (viral disease), the mean severity was low (S_m = 2.95) in the sites surveyed. It ranged from 2.64 to 3.23 in Nyanga and Woleu-Ntem provinces respectively. Nearly four of the nine provinces had a high mean severity (Sm> 3), namely Haut-Ogooué, Moyen-Ogooué, Ogooué-Ivindo and Woleu-Ntem. In contrast, the rest of the provinces recorded a low mean severity (Sm< 3) (Table 6).

Table 6 . The mean severity of cassava diseases according to provinces

Provinces	Mosaic	Bacteriosis	Anthracnose	Leafnecrosis	Root rot
Estuaire	2.73	-	2.87	2.61	-
Haut-Ogooué	3.14	3	3.07	3.03	-
Moyen-Ogooué	3.04	3	2.88	2.22	2
Ngounié	2.89	-	3.08	2.87	-
Nyanga	2.64	-	2.73	2.57	-
Ogooué-Ivindo	3.15	-	3.02	3	-
Ogooué-Lolo	2.87	-	3.03	3.02	-
Ogooué-Maritime	2.88	3	3.35	2.6	-
Woleu-Ntem	3.23	-	2,98	2.5	3.22
Mean	**2.95**	**3**	**3**	**2.71**	**2.61**

3.6.2. Severity levels of bacterial diseases by province

As for bacterial diseases, cassava bacterial blight had a high mean severity (S_m = 3) in the study area. It was high (S_m = 3) in three (3) provinces: Haut-Ogooué, Moyen-Ogooué and Ogooué-Maritime. However, the mean severity was very low in the other provinces (Table 6).

3.6.3.Severity levels of fungal disease by province

As far as fungal diseases are concerned, anthracnose was the most widespread fungal disease in the study area. Its mean severity (S_m) was high in all provinces. In fact, five provinces (Haut-Ogooué, Ngounié, Ogooué-Ivindo, Ogooué-Lolo, Ogooué-Maritime) showed a high mean severity (Sm = 3). However, individual mean severity values were similar within each province explored (S_m =2.87-3.35).

Leaf necrosis showed themean severity levels of S_m = 2.71 for the entire study area. The mean severity at provincial level ranged from 2.22 (Moyen Ogooué) to 3.03 (Haut-Ogooué, Ogooué-Ivindo, Ogooué-Lolo).

Finally, root rot, the third fungal disease, showed mean severity levels of 2.61 throughout the study area. However, the highest severity was observed in the provinces of Woleu-Ntem (S_m = 3.22) and Moyen-Ogooué (S_m = 2), while the lowest severity was recorded in the rest of the provinces surveyed (Table 6).

3.7. Analysis of correlations between incidence and severity of different diseases

Pearson's test results showed that there was a significant positive correlation between the mean incidence and mean severity of mosaic, anthracnose and leaf necrosis ($r_1 = 0.52$; $p_1 = 0.74$; $r_2 = 0.48$; $p_2 = 0.18$; $r_3 = 0.74$; $p_3 = 0.02$) (Figure 5).

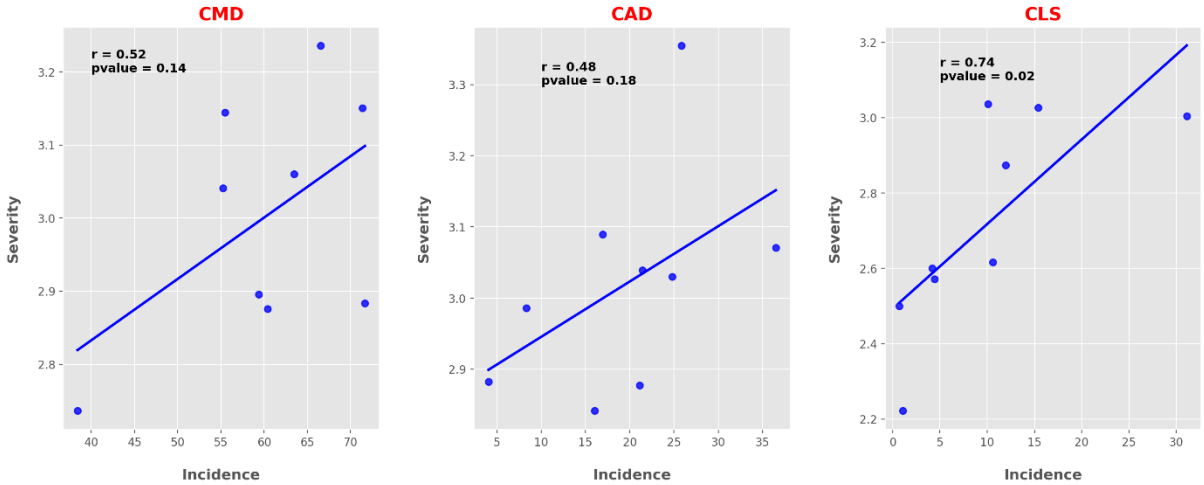

Figure 5. Correlation between incidence and severity of identified cassava diseases. r: correlation coefficient.

3.8. Level of knowledge of cassava mosaic disease by the farmers

The results in Table 7 show that in almost all of Gabon's provinces, cassava mosaic is an unknown disease by farmers (82.92%; p = 0.00074). The provinces of Ogooué-Maritime (100%), Ngounié (95.45%), Nyanga (95.24%) and Ogooué-Lolo (94.5%) have high proportions of farmers who are unaware of cassava mosaic disease. On the other hand, Estuaireis the province where cassava farmers are most aware of the disease (33.33%), followed by Haut-Ogooué (25%).

Table 7. Percentage of farmers familiar with the mosaic disease in the study area

	Knowledges of mosaicdisease	
Provinces	**No**	**Yes**
Estuaire	66.67	33.33
Haut-Ogooué	75	25
Moyen-Ogooué	89.29	10.71
Ngounié	95.45	4.55
Nyanga	95.24	4.76
Ogooué-Ivindo	88.89	11.11
Ogooué-Lolo	94.5	5.5
Ogooué-Maritime	100	0
Woleu-Ntem	89.28	10.71
Mean	**82.92**	**17.09**

4. DISCUSSION

As part of this epidemiological study, it was found that cassava cultivation is predominantly practiced by women over the age of 50 years. This result is in line with that of the Gabonese general agricultural censuswhich showed that the agricultural workforce is predominantlyfeminine andaged >

50 years[2]. The important role of women in slash-and-burn agriculture has already been demonstrated byBahuchetand Betsch [27], and Pourtier[28]. The involvement of the elderly persons in the food production system could be linked to the fact that agriculture is an activity considered like marginal and secondary by Gabonese people. Moreover, the high rate of rural exodus in the country caused the predominance of elderly people in villages[14].

The interviewed famers cultivate cassava without tilling the soil on clay soils, in association with other agricultural crops[27, 29]. This observation is probably linked to cultural habits and farmers' lack of training. This has already been demonstrated by several authors[27, 29].

In addition, the present study has shown that cassava is subject to several stresses, including viral, bacterial and fungal diseases. The symptomatologic diagnosis identified five different cassava diseases (mosaic, bacterial blight, anthracnose, leaf necrosis, root rot) in the cassava fields explored, with different levels of mean incidence and mean severity depending on the province. According toKomba andSemballa[30],bacterial and fungal pathologies cause more yield losses when associated with mosaic than alone, as is the case in Gabon. Thus, the low productivity of cassava plantations recorded nationwide and the damage deplored could be linked to the high incidence of cassava mosaic and/or to the combination of viral, fungal and bacterial diseases on cultivated plants, and to a lesser extent, to the incidence of anthracnose.

Among the diseases identified during the present study, mosaic was the most frequently observed in the plantations Its mean incidence was high, accounting for more than 2/3 of the overall cassava diseases encountered in the fields visited. This is probably due to the fact that the farmers interviewed were generally unaware of mosaic disease and might have acquired their cassava cuttings by self-propagating plant material that were already infected with the virus[7]. This result was also reported by Zinga *et al.*[11], who conducted a study on the effects of African cassava mosaic disease in the Central African Republic.

This mosaic disease is widely distributed in Gabon, with a mean incidence of 60.22% and a mean severity of 2.95 in the study area with variations withinthe provinces as previously reported by [7]. This trend was reinforced by Pearson's tests, which confirmed that there is a positive and significant correlation between the mean incidence and mean severity of diseases such as cassava mosaic, anthracnose and leaf necrosis. This result is similar with observations made by Mouketou*et al.*[7] in Gabon. Several authors have previously reported the existence of this virus disease in Gabon [7,12, 13]. Moreover, this disease has already been reported in several Central African countries as the primary threat to cassava cultivation[11], [31], [32]. This viral disease is caused by a geminivirus transmitted by a vector, whitefly, belonging to the species *Bemisiatabaci*(Gennadius) (Hemiptera: Aleyrodidae) [31], [33].

The spatial distribution of the mean incidence and mean severity of cassava mosaic across the different fields surveyed in Gabon is relatively homogeneous from one province to another (I_m = 60.22%; S_m =2.95). The spread of this disease across the country could be encouraged by bad agricultural practices. Indeed, the continued use of infected self-produced cuttings, traditional seed

production methods and the exchange of planting materials between growers are factors that could explain the high incidence and severity of the disease in the cultivation zones surveyed. This result was reported byOwor *et al.*[34] who worked on the effects of mosaic disease in cassava varieties in eastern Uganda. They reported that repeated use of contaminated planting material would increase the viral load in plants.

Anthracnose (I_m = 19.45; S_m = 3) ranked second in terms of disease incidence diagnosed in the study area. It was distributed across all the agro-ecological zones explored. It was expressed heterogeneously from one province to another. Low values of cassava anthracnose incidence have also been reported in cassava fields in Cameroon [35]. Several other authors have reported the existence of this disease in Africa, notably in Congo Brazzaville (I_m =90%), Côte d'Ivoire , Cameroon , Nigeria and the Democratic Republic of Congo (I_m =80%), with very high incidences [36–39]. High values for the mean severity of cassava anthracnose disease were observed in all the localities visited. This could be due to the high humidity and warm temperatures characteristic of the Gabonese climate. Indeed, Makambila[26]reported that cassava anthracnose develops best in environments with a relative humidity of 87% and temperatures between 24°C and 28°C. Furthermore, in a study conducted by Mogo *et al.*[39] in farmers' plantations in the southern Cameroon region, the authors found that the severity of this disease is higher when relative humidity is high.

The incidence of cassava leaf necrosis was low in all agricultural zones. Overall, the low incidence of leaf necrosis in all the provinces surveyed could be explained by the age of the crops, as the mean age of the plants observed was between 3 and 6 months. According toMahungu*et al.*[40], the disease incidence is higher inolder cassava plants especially, when planted on acid soils. In addition, the mean severity of the disease was lower than that observed for cassava mosaic disease, supporting the low incidence of the disease. Globally, cassava leaf necrosis disease is considered less destructive than other diseases such as cassava mosaic disease[41]. However, special attention is needed because Wydra and Verdier[42] have observed that cassava leaf necrosis is widespread in humid zones, and the severity of this disease increases with the number of surrounding trees and common with cassava varieties with strong branches.

Cassava bacterial blight and root rot were rarely observed in the plantations explored. The mean incidence of these two diseases was very low (I_m =0.5%)compared with other cassava diseases. Their mean severity values varied with a more severe degree of disease in bacteriosis(S_m = 3)compared with root rot (S_m =2.61). Data on root rot may be significantly underestimated in this study, as our field observations were made on young crops less than 6 months after planting. Root rot has already been reported in Central Africa, notably in Gabon[5] and in the Republic of Congo [36]. These studies revealed that the disease is widespread mainly in rainforest areas. Other studies have shown that the damage caused by root rot is more significant when the period of root retention in the soil is prolonged [43, 44].

These authors revealed that root rot disease is present in these countries, especially, in humid forest areas[43, 44]. In addition, the majority of farmers interviewed stated that they very often observe cassava root rot at harvest time (9-12 months after planting). In fact, studies carried out by

Makambila[43],Makambila andKoumouno[44] in Republic of Congo have shown that the damages caused by root rotbecome more serious when roots over stay in the soil.

As for farmers' knowledge of mosaic disease, this study revealed that the majority of cassava growers in the study area were unaware of this virus disease. Ignorance of the disease is higher in the other provinces than in Estuaire and Haut-Ogooué. This observation is probably linked to the fact that people in these provinces have benefited from several training courses and agricultural development projects focusing on cassava, such as the FAO Regional Cassava Initiative, the Integrated Protection of Cassava against Emerging Pests and Diseases Threatening Rural Households project, Sustainable Cassava Production in Central Africa and Market Integration, the Central and West African Virus Epidemiology for food security (WAVE) program, etc. This ignorance of the disease, its causes and vectors, is not unique to farmers in Gabon. For example,Chikoti *et al*. [45] noted that nearly 97.6% of farmers in Zambia are unable to identify and recognize cassava mosaic. In Benin, Houngue*et al.*[46] found that some 92.60% of growers were unaware of the causes and the vectors of the mosaic disease.

This situation calls urgently for an effort of researchers and extension agents to raise awareness and train cassava growers, as farmers who recognized the symptoms of cassava diseases claimed to have been sensitized and trained by extension agents under certain agricultural development projects.

5. CONCLUSION

This study is the first epidemiological study on a national scale to highlight the limiting diseases of cassava cultivation. The results of this study demonstrate that cassava growing in Gabon is essentially adversely affected by pathogens: viral, bacterial and fungal origins. These are, the order of incidence: cassava mosaic disease, anthracnose, leaf necrosis, bacteriosis and root rot. However, cassava mosaic disease remains the most widespread disease in Gabon, with a high level of incidence. It is therefore the most prevalent and the cause of productivity constraints for cassava cultivation in Gabon. This strategic food crop for the Gabonese people deserves special attention and should be protected against these diseases.

This study, aimed at diagnosing cassava pathologies in Gabon, was conducted essentially on the basis of disease symptomatology. These preliminary results should be supported by molecular analyses to characterize the viral, bacterial and fungal strains responsible for the various cassava diseases identified during the epidemiological surveys.

In addition, the wide distribution of mosaic, its high incidence and severity across the country's administrative provinces, support the hypothesis of a spread of the diseaseis facilitated by the use of contaminated cassava cuttings by farmers. To combat this disease effectively, it is important to organize awareness-raising campaigns and training workshops for cassava growers on techniques for sanitizing contaminated cassava cuttings and propagating healthy planting materials, and on

recognizing the pests and symptoms of viral, bacterial and fungal diseases encountered in cassava production basins in Gabon.

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