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Seasonal Variation on the Incidence and Severity of Major Foliar Diseases of Cassava in Sierra Leone

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Abstract

A diagnostic survey was conducted in the rainy and dry seasons from 2014 to 2015 to determine the incidence and severity of major diseases of cassava in Sierra Leone. At least three chiefdoms and five villages per district were targeted. The survey was carried out in fourteen districts of the country with geo references using a GPS. On the spot assessment was conducted in all fields. Prevalence, severity and incidence were calculated. The most dominant diseases included the cassava mosaic disease and the cassava bacterial blight. The prevalence of cassava mosaic disease was high with 69.1% and 61.5% in the rainy season and dry season, respectively. The prevalence of cassava bacterial blight was 100% and 92% in the rainy season and dry season, respectively. Diseases of less importance included white spot and brown spot diseases as well as cassava anthracnose disease. The study provides bases for the deployment of improved varieties and provides information on the seasonal prevalence, incidence and severity of cassava diseases in Sierra Leone.

Keywords: Cassava Diseases, Incidence, severity and distribution

1. Introduction

Cassava (*Manihot esculenta* Crantz, family: Euphorbiaceae synonyms: yucca, manioc, and mandioca), a native to South America, is believed to have been introduced into Sierra Leone during the period of slave trade proliferated by Portuguese traders during the 16th century [1]. Cassava is grown over a range of climates and altitudes and on a wide variety of soils and ecologies. These includes the lowlands and uplands as commonly practised in Sierra Leone. Cassava is tolerant to drought; it is productive in poor soil where other staple crops cannot grow without intensive inputs [2]. The crop has long been recognized as an important source of carbohydrate for over 500 million people in Africa as well as feed for livestock, providing higher food energy production density (1045 kJ/hectare) than other root crops, such as maize grain (836 kJ/hectare) and fresh sweet potato root (752 kJ/hectare) [3]. The flexibility in growth conditions entertained by the cassava crop enables it

to grow successfully under a wide range of agro-ecological zones where cereals and other crops cannot thrive, making it a suitable crop for resource-poor farmers to cultivate under marginal environments in Africa. The other attraction for farmers to grow cassava is that it produces higher yields per unit of land than other crops such as rice, sweet potato, wheat, sorghum, maize and banana fruit [3]. The pivotal role of cassava in the lives of Africans is evident from many documents [4, 5]. In Sierra Leone, cassava is the second most important food crop after rice the country's staple. It is also the most important root and tuber crop [6]. Cassava is also grown all over the country which has shown remarkable progress in cassava processing at both domestic and commercial scales, although to varying degrees. Some common cassava products processed in the country include *gari*, foo-foo, gbodor, dried chips, starch and boiled cassava with beans. Cassava-based products such as raw tubers, *gari* and cassava bread (very thin, small, flat, round pieces) are traded mainly in Sierra Leone [7]. Cassava leaves provide a source of income for women. The leaves are used to prepare a very popular national cassava leaf sauce [6]. Much of this success may be attributed to its adaptability, its capacity to provide acceptable yields under marginal farming conditions and its tolerance to drought [8].

According to the Food and Agriculture Organization of the United Nations (FAO) statistics, Sierra Leone is one of the lowest cassava producing countries in the world with an estimated yield of 13.2 t/ha [9]. A substantial increase in production was observed from 95,000mt in the '80s to 241,000mt in 2000 and is now estimated at 4,588,612 tons with 346,266 ha harvested area [7, 9].

As part of the World Bank's strategy for increasing the productivity of cassava in West Africa, the West Africa Agricultural Productivity Programme introduced new varieties of cassava, intensified production in terms of land area and processing of cassava countrywide. This situation if not monitored could lead to a high incidence of pests and diseases as the crop is grown more intensively over larger areas and planted throughout the year for industrial processing [10].

Cassava is affected by the following principal diseases: Cassava mosaic disease (CMD) is perhaps the most important diseases of cassava. Cassava brown streak virus disease associated with tuber rot and other virus diseases [4]. Two virus diseases, CMD and cassava brown streak disease (CBSD) are both thought to have risen from infection of cassava by viruses already present in the indigenous Africa flora [8].

It has been estimated that cassava bacterial blight (*Xanthomonas axonopodis* pv. *manihotis*) can account for 30% loss of yield in one growing cycle, and up to 80% by the third cycle if no control measures are taken [11]. Other diseases of importance include Cassava Anthracnose Disease (CAD) caused by *Colletotrichum gloeosporioides* f.sp. *manihotis* Henn, also introduced from South America in the 1970s, and to a lesser degree cercosporiosis caused by *Cercosporidium henningsii* [8, 12].

Following the success of the cassava mealybug and cassava green mite biological control programs, CMD and CBSD have become prominent in research and management initiatives, and CMD is now commonly considered to be the most damaging pest or disease constraint to cassava production in Africa. Cassava mosaic disease (CMD) caused by cassava mosaic geminiviruses (CMGs) (family Geminiviridae; genus *Begomovirus*) is widely distributed throughout Sierra Leone [13]. Cassava bacteria blight is emerging as an economic disease especially for the cassava leaf producers and markets. The disease has become more important due to an increase in symptom expression which can be attributed to changing climatic condition [14].

There is however a dearth of knowledge on the incidence, severity and distribution of cassava diseases in Sierra Leone. As a one-year duration crop, there is also limited information on the incidence and severity of diseases during the rainy and dry season. Knowledge of the incidence, severity and distribution of major diseases is critical for the deployment of germplasm in the management of these biotic

stresses. Potential threats include the re-emergence of new viruses, higher incidence and severity of diseases due to variation in weather and to a greater extent the lack of response due to lack of information on the level and location of biotic threats which may lead to a huge economic loss.

2. Description of field sampling methodology and analysis

Two surveys were conducted in 2014 and 2015 to assess the seasonal variability of major diseases associated with cassava in farmers' field across Sierra Leone. The survey routes were determined using the road maps of Sierra Leone and such routes included highways, secondary roads and feeder roads. The routes were selected to target major cassava growing areas within the geopolitical districts as well as the major agro-ecologies in Sierra Leone. The distance between farms ranged between 2 and 3 Km in small chiefdoms and 3–5 Km in big chiefdoms. In each district, both primary (3–6 months) and secondary fields (more than 10 months) were sampled. In both primary and secondary fields, the predominant cassava variety was sampled although other varieties were noted. In the primary fields, 30 cassava plants were sampled at regular intervals using a diagonal transect, while in the secondary field, 10 plants were sampled at regular intervals along the field's diagonals. Three chiefdoms per district were targeted. The rainy season survey was conducted for twenty (20) days, July 8 to 28, 2014; and covered thirteen out of fourteen districts (including Bo, Bonthe, Pujehun, Moyamba, Port Loko, Koinadugu, Kambia, Tonkolili, Bombali, Kono, Western area (Urban and Peri-Urban) and Kenema). Kailahun district was not sampled because of the Ebola threat. The dry season survey was conducted in the dry season from 11th February to the 2nd March 2015. The survey was carried out in all fourteen districts of the country. A total of one hundred and seventy-two (172) and one hundred and ninety-five (195) cassava farms were visited countrywide in the rainy and dry seasons, respectively.

At each site data were taken on location including coordinates (altitude, latitude and longitude) using GPS sets GARMIN eTrex Legend 1200 E 151st Street, Olathe, Kansas 66062 U.S.A) from which GIS maps were generated for cassava diseases assessed.

The age and size of each field were noted; information on crop age was obtained from the farmers and the size of the field determined from visual estimation. The cropping systems, names of each cassava variety and whether it was local or improved was also noted. Interviews were also conducted to capture the views of men, women and youths on their knowledge on, insect pests' diseases, weeds identification and control.

On the spot assessment was conducted in all fields in the Western Area and 12 districts and 5 agro-ecologies which include the rain forest, savannah lowland, savannah highland, coastal plains and the peninsular mountain. Major diseases assessed included the African Cassava Mosaic Disease, Cassava Bacterial Blight and Cassava Anthracnose Disease. Prevalence was calculated as the number of sites infected over the total number of sites visited expressed in percentages. The severity of diseases was assessed using the five-point scale where 1 represents no visible symptom and 5 severe symptom expression [15]. Percent incidence was calculated by expressing in percent the total number of infected plants over the total number of plants sampled.

3. Key findings

The most dominant diseases included the cassava mosaic disease and the cassava bacterial blight. Cassava white spot and brown spot diseases were considered minor

but affect the esthetic value of cassava leaf. Most of the cassava mosaic infected varieties were local varieties while cassava bacterial blight infected both local and improved varieties.

3.1 Field, crop and environmental characteristics of cassava farms in Sierra Leone

The national survey, supported by the West African Agricultural Productivity Program (WAAPP) recorded the names of 25 cassava varieties of which, 88% were local varieties while 12% were improved varieties. Likewise, sixty-four percent of the farms visited had local cassava varieties while thirty-six percent of the farms had improved varieties. The most common local varieties grown were Warima, Cooking soon, Cocoa, Gendemeh, Munafa, Three-month cassava, Ndiamonyamawo, rubber and kandagboi, Nikanyeyea, Kandabendue, Cotton tree, Monobia, Mawola, Minikit, Shortman, Sameteteh, Sweet cassava, and Yakanu Pa Jalloh [13]. The improved varieties recorded were Slicass 1, Slicass 4, Slicass 6 and Slicass 3.

At the district level, more improved varieties were grown in Bonthe (100%), Moyamba (60.00%), Pujehun (60.00%) and Kambia (46.67%) (**Table 1**). On the other hand, local varieties were grown predominantly in Kailahun (100%), Kono (93.33%), Bo (93.33%), Port Loko (93.33%) Kenema (86.66%), Koinadugu (86.67%), Tonkolili (86.67%), Bombali (86.67%) and Western Area (76.92%), respectively (**Table 1**).

Mean cassava field size ranged from 0.22 hectare in Western Area to 2.70 hectares in the Bonthe district (**Table 1**). The mean age of the cassava fields ranged from 3.86 months in Bombali district to 12.80 months in Moyamba district. The mean altitudes of the fields in the thirteen locations ranged

| District | Average farm size (Ha) | Average altitude (M) | Average age of farm (Month) | Variety grown by Farmers | |
|--------------|------------------------|----------------------|-----------------------------|--------------------------|--------------|
| | | | | Local (%) | Improved (%) |
| Bo | 1.12 | 98.93 | 11.60 | 93.33 | 6.67 |
| Pujehun | 1.41 | 59.33 | 11.73 | 40.00 | 60.00 |
| Moyamba | 1.25 | 73.13 | 12.80 | 40.0 | 60.00 |
| Bonthe | 2.70 | 47.0 | 12.0 | 0 | 100.00 |
| Kenema | 0.73 | 168.13 | 11.73 | 86.66 | 13.34 |
| Kono | 0.69 | 369.40 | 9.80 | 93.33 | 6.77 |
| Kailahun | 0.51 | 200.53 | 12.00 | 100.00 | 0.00 |
| Bombali | 1.06 | 90.53 | 3.86 | 86.66 | 13.34 |
| Koinadugu | 0.23 | 382.26 | 4.33 | 86.67 | 13.33 |
| Kambia | 0.52 | 53.80 | 7.06 | 53.33 | 46.67 |
| Port Loko | 0.65 | 56.33 | 9.40 | 93.33 | 6.67 |
| Tonkolili | 0.82 | 148.93 | 9.00 | 86.67 | 13.33 |
| Western Area | 0.22 | 107.23 | 8.92 | 76.92 | 23.08 |

Source: Cassava pest and disease survey conducted in 2014, supported by the West African Agricultural Productivity Program (WAAPP).

Table 1.
Field crop and environmental characteristic.

from 47.00 m above sea level in Bonthe district to 382.26 m above sea level in Koinadugu district [14].

3.2 Seasonal prevalence of major diseases of cassava in Sierra Leone

The prevalence of cassava mosaic disease in the rainy season was 69.1% out of one hundred and seventy-two (172) farms sampled. During the dry season, the prevalence was recorded at 61.5% out of one hundred and ninety-five (195) farms sampled (Table 2).

Figure 1a–d shows the expression of diseases infected cassava and an improve variety.

| Major foliar cassava diseases | Prevalence | |
|-------------------------------|--------------|------------|
| | Rainy season | Dry season |
| Cassava Mosaic disease | 69.1 | 61.5 |
| Cassava Bacterial blight | 100 | 92 |
| Cassava anthracnose disease | 6.9 | 29.7 |
| Cassava brown spot disease | 1.16 | 22.5 |
| Cassava White spot disease | 5.2 | 36.9 |

Table 2.
Prevalence of major diseases of cassava in 2014/2015.



Figure 1.
a. Cassava plant infected cassava mosaic disease observed in 2014/2015; b. cassava plant infected cassava bacteria blight 2014/2015; c. cassava plant infected cassava anthracnose disease observed in 2014/2015; d. healthy cassava variety observed in 2014/2015.

3.3 Incidence and severity of cassava mosaic disease in the rainy and dry season

In 2014/2015, the incidence and severity of Cassava Mosaic disease in the rainy season was significantly the highest in the Kono ($P < 0.001$) (94.3%), Koinadugu (84.3%) and Kenema (80.2%) districts. Bonthe district had the lowest incidence of 10.3% an occurrence attributed to the break down in resistance of the popular released variety SLICASS 4 commonly referred to as blue boat. The Western Area had a disease incidence of 24.7% followed by Pujehun and Moyamba with an incidence of 32% and 37% respectively. Port Loko, Kambia and Tokolili districts had diseases incidence ranging between 56.3% to 66.7%.

The severity of the cassava mosaic disease across districts was generally considered to be moderately infected with a significant ($p < 0.001$) difference between districts. Kenema had the highest severity score of 2.8 followed by Kono, Tonkolili and Bombali with severity scores of 2.6, 2.3 and 2.2 respectively. Bonthe district had the lowest severity score of 1.1 followed by Moyamba, Pujehun and Bo with a severity score of 1.7, 1.7 and 1.8 respectively (**Table 3**).

In the dry season, the incidence of cassava mosaic disease was significantly different across districts. The highest incidence of 86.7% was observed in Kono. Bombali and Tonkolili had incidence 74.7% and 73.3% respectively. Bonthe district had the lowest incidence of 0% followed by Kailahun 29.8, Bo 41.9%, Kambia 46.7% and Moyamba 48.1%.

The severity of the cassava mosaic disease across districts was generally considered to be moderately infected with a significant difference between districts. Kono, Koinadugu, Bombali and Kambia had the highest severity score of 1.9, 1.85, 1.82 and

| District | White Spot | | Cassava Mosaic Disease | | Cassava Anthracnose Disease | | Cassava Bacteria Blight | |
|--------------|---------------|----------|------------------------|----------|-----------------------------|----------|-------------------------|----------|
| | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity |
| Bo | 5 | 1.1 | 43.7 | 1.8 | 8.7 | 1 | 94.3 | 2 |
| Bombali | 0 | 1 | 57 | 2.2 | 3 | 1 | 97.7 | 2.1 |
| Bonthe | 12 | 1.1 | 10.3 | 1.1 | 2 | 1 | 90.7 | 1.9 |
| Kambia | 0 | 1 | 65 | 2.2 | 0 | 1 | 96 | 2.1 |
| Kenema | 1.1 | 1 | 80.3 | 2.8 | 0 | 1 | 99.7 | 2 |
| Koinadugu | 0 | 1 | 84.3 | 2.3 | 0 | 1 | 100 | 2 |
| Kono | 0 | 1 | 94.3 | 2.6 | 2 | 1 | 100 | 2.2 |
| Moyamba | 0 | 1 | 36 | 1.7 | 0 | 1 | 100 | 2 |
| Port Loko | 0 | 1.1 | 56.3 | 1.9 | 0 | 1.2 | 98 | 2.3 |
| Pujehun | 6.7 | 1 | 32 | 1.7 | 5 | 1.2 | 88 | 2 |
| Tonkolili | 0 | 1 | 66.7 | 2.3 | 0 | 1 | 100 | 2.2 |
| Western Area | 0 | 1 | 23.7 | 1.4 | 1 | 1 | 100 | 2.1 |
| SE± | 2.39 | 0.04 | 10.2 | 0.3 | 2.6 | 0.05 | 4.1 | 0.09 |
| CV(%) | 448.7 | 11.9 | 73 | 45 | 565.8 | 20.3 | 11.7 | 17.7 |

Table 3.
Incidence and severity of major disease of cassava in the rainy season in Sierra Leone in 2014/2015.

| District | White Spot | | Cassava Mosaic Disease | | Cassava Anthracnose Disease | | Cassava Bacteria Blight | | Brown Spot | |
|--------------|---------------|----------|------------------------|----------|-----------------------------|----------|-------------------------|----------|---------------|----------|
| | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | severity |
| Bo | 32.5 | 1.35 | 41.9 | 1.48 | 26.5 | 1.37 | 68.8 | 1.71 | 0 | 1 |
| Bombali | 8.3 | 1.14 | 78.7 | 1.82 | 0 | 1 | 49.7 | 1.5 | 0 | 1 |
| Bonthe | 52.9 | 1.52 | 0 | 1 | 42.9 | 1.38 | 59.6 | 1.7 | 0 | 1 |
| Kailahun | 29.4 | 1.34 | 29.9 | 1.3 | 13.8 | 1.17 | 79.9 | 1.85 | 0 | 1 |
| Kambia | 33.3 | 1.33 | 46.7 | 1.8 | 6.7 | 1.1 | 100 | 2.54 | 50 | 1.5 |
| Kenema | 13.6 | 1.13 | 45.9 | 1.47 | 0.5 | 1.1 | 84.7 | 3.35 | 0 | 1 |
| Koinadugu | 5 | 1.05 | 74.7 | 1.85 | 0 | 1.1 | 42 | 1.51 | 3 | 1 |
| Kono | 33.7 | 1.35 | 86.7 | 1.9 | 2.3 | 1 | 75 | 1.94 | 2.3 | 1 |
| Moyamba | 38.1 | 1.38 | 48.1 | 1.49 | 31.3 | 2 | 76.2 | 1.79 | 9.1 | 1.1 |
| Port Loko | 0 | 1 | 57 | 1.58 | 20.3 | 1.2 | 77.7 | 1.93 | 15.7 | 1.2 |
| Pujehun | 37 | 1.4 | 30.3 | 1.35 | 44.7 | 1.5 | 71.7 | 1.69 | 7 | 1.1 |
| Tonkolili | 25 | 1.2 | 73.3 | 1.81 | 31.3 | 1.3 | 82.3 | 1.98 | 33.3 | 1.3 |
| Western Area | 0 | 1 | 20.8 | 1.22 | 11.97 | 1.1 | 51.1 | 1.53 | 0 | 1 |
| SE± | 13.48 | 0.14 | 16.04 | 0.195 | 8.46 | 0.28 | 14.49 | 0.53 | 8.75 | 0.08 |
| CV(%) | 155.9 | 31.6 | 91 | 34.8 | 188 | 61.4 | 56.1 | 75.8 | 273.6 | 22.5 |

Table 4.
Incidence and severity of major disease of cassava in the dry season in Sierra Leone in 2014/2015.

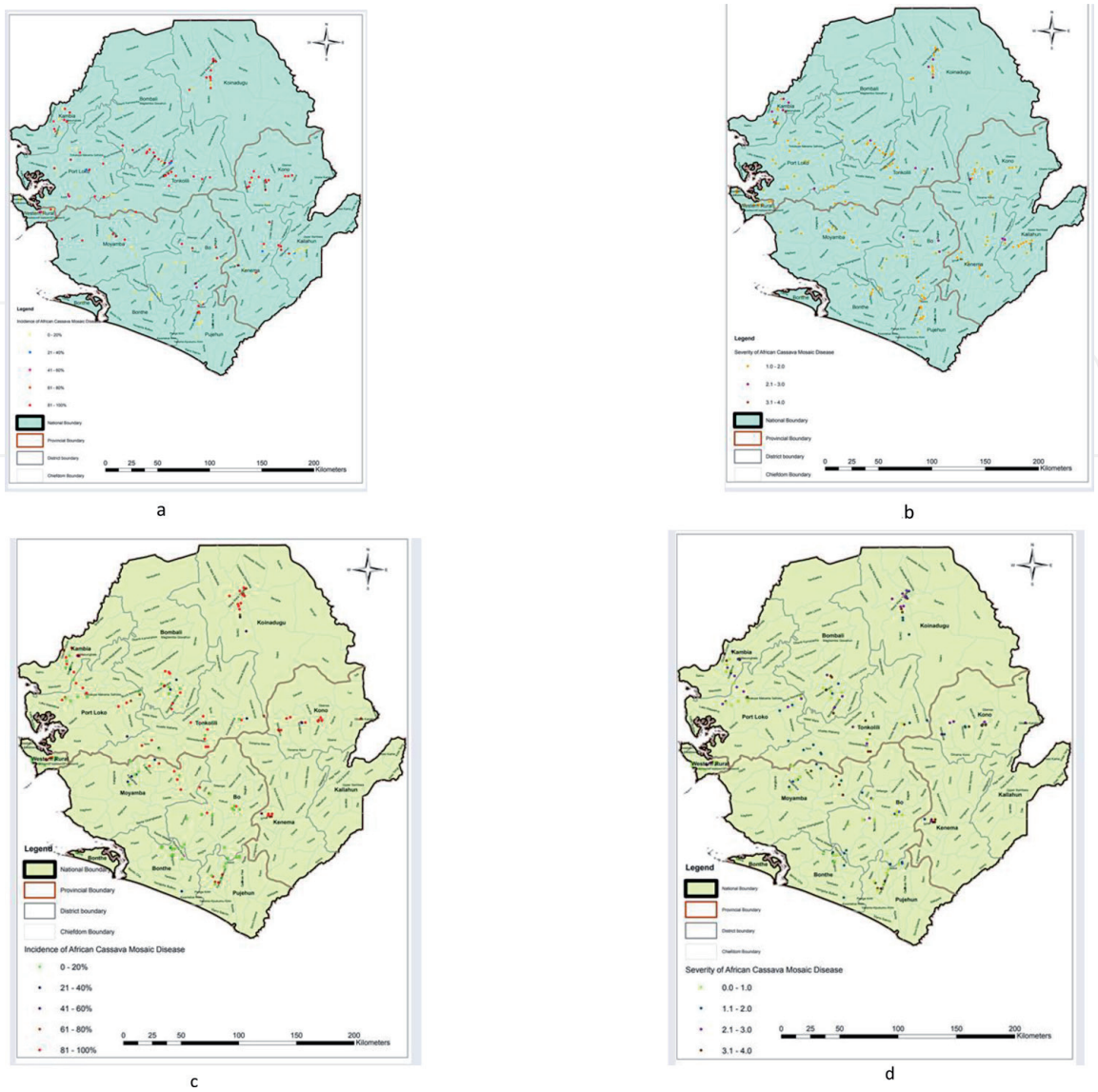


Figure 2.
a. Incidence of cassava mosaic disease dry season 2014/2015; b. severity of cassava mosaic disease in the dry season 2014/2015; c. incidence of cassava mosaic disease rainy season; d. severity of cassava mosaic disease in the rainy season 2014/2015.

1.8 respectively. Bonthe district and the western area had the lowest severity score of 1.0 and 1.2 followed by Kailahun (1.3) and Pujehun (1.35) **Table 4**.
The distribution of cassava mosaic disease across the country was represented in spatial distribution in **(Figure 2)**.

3.4 Incidence and severity of cassava bacterial blight disease in the rainy and dry season

In the rainy season, the incidence of cassava bacterial blight was high with a significant difference across districts. Koinadugu, Kono, Moyamba, Tonkolili and the Western Area districts had an incidence of 100%. The lowest disease incidence of 88% was observed in the Pujehun district. All other districts recorded an incidence of 90% and above. The severity of cassava bacterial blight was low despite the high incidence recorded. Severity ranged between 2.0 and 2.3 with no significant difference across districts **(Table 3)**.
Incidence and severity of cassava bacterial blight disease in the dry season was high with a significant difference across districts. The highest incidence of 100%

was observed in Kambia, followed by Kenema (84.7%) and Kailahun 79.9. The lowest disease incidence of 49.7% was observed in the Bombali district. All other districts recorded an incidence of 90% and above. The severity of cassava bacterial blight was low despite the high incidence recorded. Severity ranged between 2.0 and 2.3 with no significant difference across districts (**Table 4**). The distribution of cassava bacterial blight disease across the country was represented in spatial distribution in (**Figure 3**).

3.5 Incidence and severity of cassava anthracnose disease

The incidence of cassava anthracnose disease in the rainy season was low across districts with no significant difference. In most districts including Kambia, Kemema, Koinadugu, Moyamba, Port Loko and Tonkolili no symptom of cassava anthracnose disease was observed in the rainy season, However, Bo, Bombali, Bonthe, Kono and Pujehun had an incidence of 8.7%, 3%, 2%, 2%, and 5% respectively. The severity of Cassava anthracnose was also low and, in most cases, did not exceed a severity score of 1.2 **Table 3**.

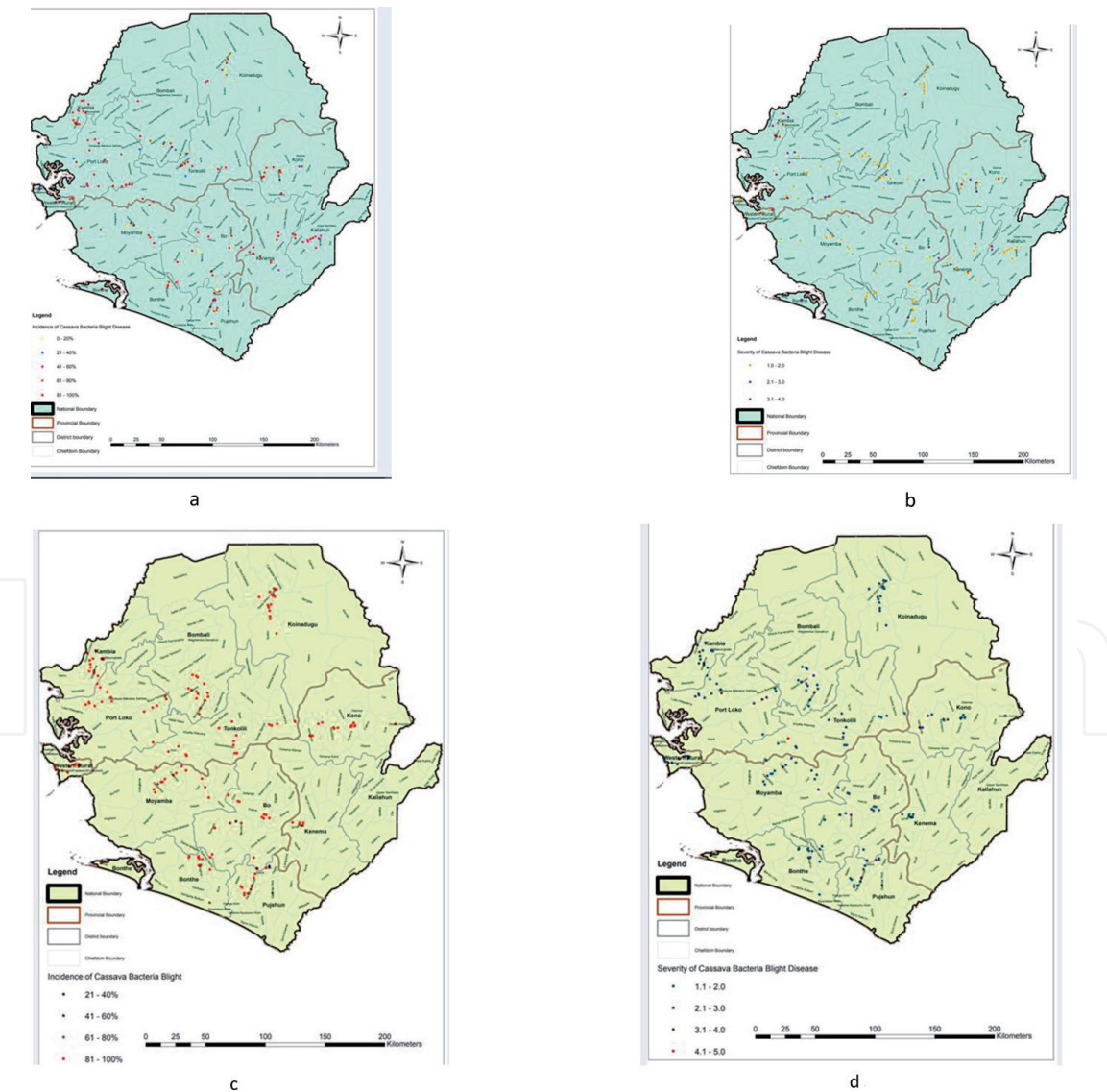


Figure 3.
a. Incidence of cassava bacterial blight in the dry season 2014/2015; b. severity of cassava bacterial blight in the dry season 2014/2015; c. incidence of cassava bacterial blight in the rainy season 2014/2015; d. severity of cassava bacterial blight in the rainy season 2014/2015.

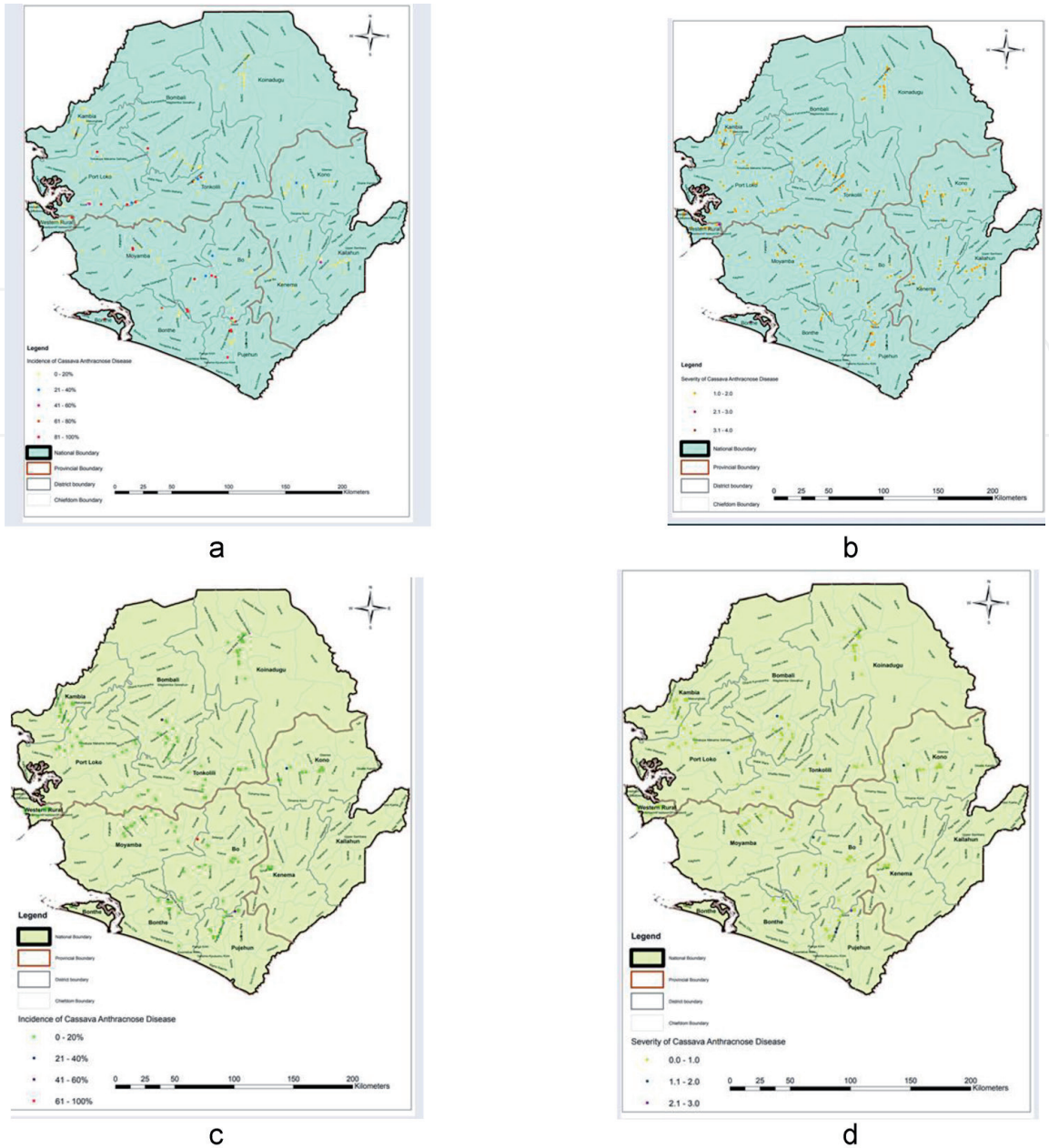


Figure 4.
a. Incidence of cassava anthracnose disease in the dry season 2014/2015; b. severity of cassava anthracnose disease in the dry season 2014/2015; c. incidence of cassava anthracnose disease in the rainy season 2014/2015; d. severity of cassava anthracnose disease in the rainy season 2014/2015.

The incidence of cassava anthracnose disease was also low in the dry season with a significant difference across districts. Pujehun and Bonthe districts had the highest incidence of 44.7 and 42.9% respectively. Bombali and Koinadugu recorded a disease incidence of 0%. The severity of Cassava anthracnose was also low. Pujehun had the highest disease severity score of 1.46 followed by Bonthe with 1.38 **Table 4**. The distribution of cassava anthracnose disease (CAD) across the country was represented in spatial distribution in (**Figure 4**).

3.6 Incidence of cassava brown spot disease

The incidence of cassava brown spot disease was low and was observed only in the dry season. The highest incidence of 50% was observed in Kambia followed by Tonkolili with 33.3%. Except for Koinadugu, Kono, Moyamba, Port Loko and Pujehun districts with incidence ranging between 2–7%, all other districts recorded an incidence of 0%. The severity score was low and did not exceed 1.5 across all

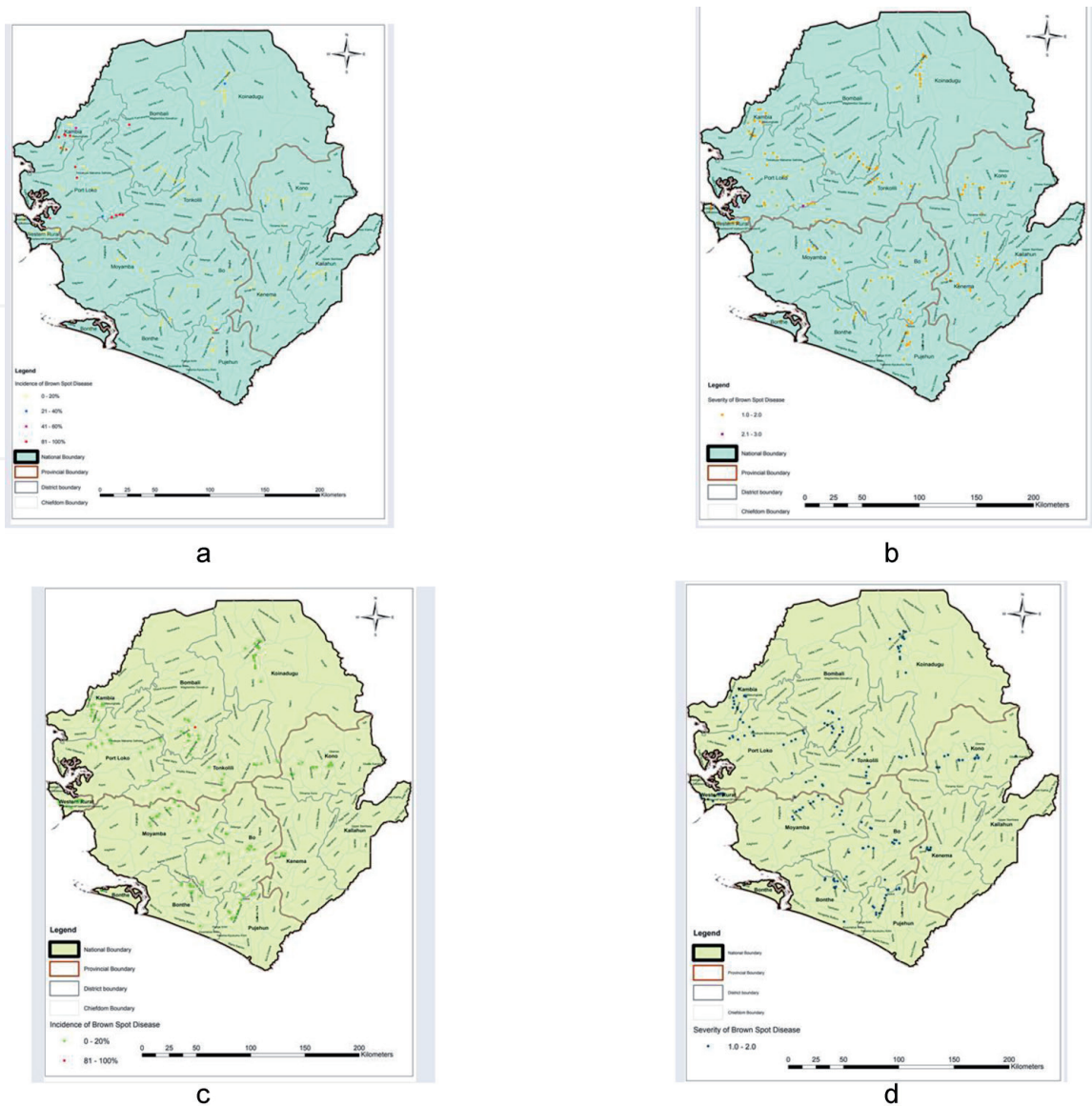


Figure 5.
a. Incidence of brown spot in the dry season 2014/2015; b. severity of brown spot in the dry season 2014/2015; c. incidence of brown spot in the rainy season 2014/2015; d. severity of brown spot in the rainy season 2014/2015.

districts **Table 4**. The distribution of cassava brown spot disease across the country was represented in spatial distribution in (**Figure 5**).

3.7 Incidence and severity of white spot disease

Incidence of cassava white spot disease was low in the rainy season. Most districts had an incidence of 0% except Bo, Bonthe, Kenema, Pujehun with disease incidence ranging between 1–612% (**Table 3**). In the dry season, the incidence of cassava white spot disease was similarly low. Port Loko and Western Area districts had no disease symptoms while Bonthe, Moyamba, Pujehun and Kono recorded diseases incidence of 52.9%, 38.1%, 37% and 33.7% respectively (**Table 4**). The distribution of the disease was represented in **Figure 6**.

3.8 Incidence and severity of major Foliar diseases of cassava across agro-ecologies

In the rainy season, the incidence of cassava mosaic disease across ecologies was significantly different. Peninsular Mountain in the western area had the

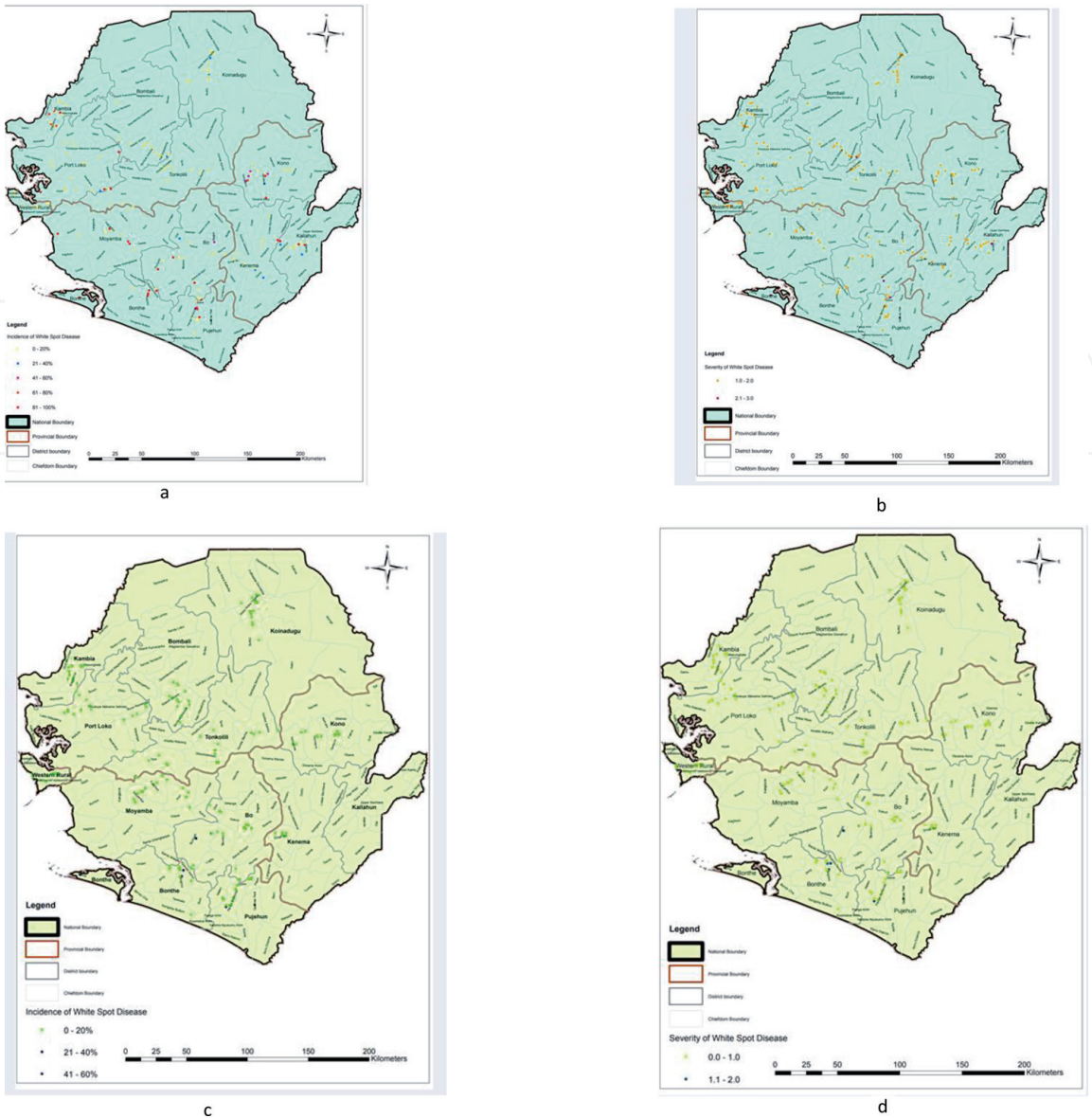


Figure 6.
a. Incidence of white spot disease in the dry season 2014/2015; b. severity of white spot disease in the dry season 2014/2015; c. incidence of white spot disease in the rainy season 2014/2015; d. severity of white spot disease in the rainy season 2014/2015.

lowest incidence of 23.7% followed by the coastal plain with 33.3%. The rain forest zone, consisting of Kenema, Kono, Kailahun, had the highest incidence of 90.1%. This was followed by the savannah highland which had an incidence of 84.3%, in the Koinadugu district. The savannah lowland, comprising the districts of Bo, Moyamba, Tonkolili, Kambia, Bombali and Pujehun had an incidence of 50.1%. The severity of the cassava mosaic disease was mild and not significantly different across agro-ecologies. The highest severity score of 2.64 was observed in the rain forest while the lowest severity score of 1.44 was observed in the Peninsular Mountain followed by the coastal plain with a severity score of 1.52 (**Table 5**).

In the dry season, however, Peninsular Mountain in the Western Area had the lowest incidence of 20.8% followed by the coastal plain with 37.4%. The savannah highland had the highest incidence of 74.7%, in the Koinadugu district. The rain forest zone, consisting of Kenema, Kono, Kailahun, an incidence of 57.0%. The savannah lowland, comprising the districts of Bo, Moyamba, Tonkolili, Kambia, Bombali and Pujehun had an incidence of 53.5%.

The severity of the cassava mosaic disease was mild with significantly different scores across agro-ecologies. The highest severity score of 1.85 was observed in

| Agro ecology | White Spot | | Cassava Mosaic Disease | | Cassava Anthracnose Disease | | Cassava Bacteria Blight | |
|---------------------|---------------|----------|------------------------|----------|-----------------------------|----------|-------------------------|----------|
| | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity |
| Coastal Plain | 6 | 1.1 | 33.3 | 1.52 | 1 | 1.05 | 94.3 | 2.1 |
| Peninsular Mountain | 0 | 1 | 23.7 | 1.44 | 0.7 | 1.01 | 100 | 2.1 |
| Rain Forest | 0 | 1 | 90.1 | 2.64 | 1.6 | 1.02 | 99.9 | 2.1 |
| Savannah Highland | 0 | 1 | 84.3 | 2.3 | 0 | 1 | 100 | 2 |
| Savannah Lowland | 0 | 1 | 50.1 | 2 | 2.75 | 1.04 | 96 | 2.1 |
| SE± | 2.6 | 0.03 | 11.53 | 0.25 | 2.86 | 0.06 | 3.25 | 0.1 |
| LSD | 5.3 | 0.06 | 29.8 | 0.58 | 5.6 | 0.11 | 6.42 | 0.2 |
| CV (%) | 476 | 12.2 | 75 | 46.2 | 549 | 20.4 | 12 | 1.8 |
| | | NS | | | | | NS | NS |

Table 5.
Incidence and severity of major diseases of cassava across agro ecologies in the rainy season in 2014/2015.

the savannah highland while the lowest severity score of 1.2 was observed in the Peninsular Mountain followed by the Coastal Plain with a severity score of 1.38 (**Table 6**).

The incidence of cassava bacterial blight was high across agro-ecologies in the rainy season. The peninsular mountain and the savannah highland area had a 100% incidence. The rain forest had a 99.9% incidence and the lowest incidence of 94.3% was observed in the coastal plains. The severity of cassava bacterial blight was low and ranged between 2 to 2.1 with no significant difference across ecologies (**Table 5**).

A similar result was observed in the dry season. The rain forest had the highest incidence of 79.5% followed by the savannah lowland with 74.9% and the coastal plain with 72%. The savannah highland and the Peninsular Mountain had the lowest incidence of 42% and 51.2% respectively. 94.3% was observed in the coastal plains.

The severity of cassava bacterial blight was low and ranged between 1.5 to 2.5 with no significant difference across ecologies (**Table 6**).

The incidence of cassava anthracnose disease was low in all agro-ecologies with no significant difference among them. Incidence did not exceed 3%. The severity of cassava anthracnose disease was also very low. In the dry season, the incidence of cassava anthracnose disease was slightly higher than the rainy season result but low in all agro-ecologies with significant differences among agro-ecologies. The coastal plain and the savannah low land accounted for the highest incidence of 27.4% and 23.3% respectively. The savannah highland had 0% while the rain forest had 5.3%.

The severity of cassava anthracnose disease was also very low and did not exceed 1.35 for all agro-ecologies (**Table 6**).

During the dry season, the incidence of cassava brown spot disease was low in all agro-ecologies but not significantly different. The savannah lowland had the highest incidence of 17% followed by the coastal plain with 9.6% and the savannah highland with only 3%. The lowest incidence of 0% was observed in the peninsular mountain and the rain forest zone. The severity of cassava brown spot disease was also very low and did not exceed 1.2 (**Table 6**) The rainy season account shows that

| Agro ecology | White Spot | | Cassava Mosaic Disease | | Cassava Anthracnose Disease | | Cassava Bacteria Blight | | Brown Spot | |
|--------------------|---------------|----------|------------------------|----------|-----------------------------|----------|-------------------------|----------|---------------|----------|
| | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity | Incidence (%) | Severity |
| Coastal Plain | 16.7 | 1.16 | 37.4 | 1.38 | 27.4 | 1.26 | 72 | 1.9 | 9.6 | 1.7 |
| Penisular Mountain | 0 | 1 | 20.8 | 1.21 | 6.1 | 1.07 | 51.2 | 1.5 | 0 | 1 |
| Rain Forest | 26.2 | 1.28 | 57 | 1.59 | 5.3 | 1.08 | 79.5 | 2.3 | 0 | 1.3 |
| Savannah Highland | 5 | 1.05 | 74.7 | 1.85 | 0.5 | 1.07 | 42 | 1.5 | 3 | 1.1 |
| Savannah Lowland | 28.8 | 1.31 | 53.5 | 1.63 | 23.2 | 1.35 | 74.9 | 1.9 | 17 | 1.3 |
| SE± | 10.63 | 0.11 | 13.28 | 0.15 | 9.57 | 0.21 | 11.29 | 0.413 | 7.6 | 0.11 |
| LSD | 20.99 | 0.22 | 26.24 | 0.31 | 18.91 | 0.43 | 22.3 | 0.81 | 15.1 | 0.22 |
| CV (%) | 172 | 32.7 | 93.5 | 36.1 | | | 56.9 | 76.9 | 283.9 | 32.7 |

Table 6.
Incidence and severity of major diseases across agro ecology in the dry season in 2014/2015.

the incidence of cassava white spot disease was also low in all agro-ecologies with no significant difference among them. Incidence did not exceed 6%. The severity of cassava anthracnose disease was also very low and did not exceed 1.1.

The incidence of cassava white spot disease was low in all agro-ecologies but significantly different. The expression of the white spot disease was observed mostly in the dry season. The savannah lowland had the highest incidence of 28.8% followed by the rain forest with 26.2% and the coastal plain with 16.7%. The lowest incidence of 0% was observed in the peninsular mountain and the savannah highland with a 5% incidence. The severity of cassava white spot disease was also very low and did not exceed 1.3 (Table 6).

4. Discussion of the findings

The survey results showed that the Cassava Mosaic Disease (CMD) and the Cassava bacteria blight (CBB) were the most important diseases affecting cassava production [16]. The High prevalence of Cassava Mosaic Disease (CMD) in the rainy season could be attributed more to the use of susceptible local varieties. Time of planting and environmental conditions was also major factors that influence the seasonal variation observed in the expression of the diseases [17]. Higher incidence of cassava mosaic disease recorded in the dry season in Bombali, Port Loko, Kono and Tonkololi could be attributed to late planting in September to December. The project dissemination of new agricultural technologies in Africa (DONATA) highly influenced the adoption of recommended planting date (May to June) observed mostly in the southern province which consequently had lower diseases incidence as manifested in Bonthe district. The early manifestation of the disease was also attributed to the planting of infected cuttings and whitefly population [18]. This implies that the search for adaptable varieties that are high yielding and tolerant to cassava mosaic disease remains a requirement for the mass propagation of planting materials. Deployment of resistant genotypes remains the most feasible approach however consideration should be given to traits desirable to farmers. A trait such as good cooking ability fits better into the food utilization pattern a characteristic dominant among local varieties susceptible to the cassava mosaic disease.

Thomas [19] had reported a 100% incidence of the diseases in the Western Area, a situation which was reflective of the trend country-wide before this survey. The intensity however differs mostly across agro-ecologies. The much lower disease incidence and severity rating observed in this study can be attributed to the adoption of improved cassava varieties promoted by the Government of Sierra Leone and development partners. The contrasting results for the Bonthe district can best be explained by associating farmers with the cultivation of improved cassava varieties and processing machines for gari and foo-foo production, which is the major source of livelihood in the district. No clear hot spot for the Cassava Mosaic Disease was could be identified. This could be explained based on the diversity of the cassava genotypes both local and improved cultivated in Sierra Leone.

In the case of cassava bacterial blight, the high prevalence in the rainy season could also be attributed more to the use of susceptible local varieties. Time of planting and environmental conditions were considered to be the major factor that influenced seasonal variation observed in the expression of the disease.

The search for adaptable varieties that are high yielding and tolerant to cassava bacterial blight disease remain a requirement for mass propagation of planting materials. In the absence of resistant genotypes, training farmers in the identification and control of cassava bacterial blight disease within the early warning systems perspective is critical to avoid disease outbreak.

The Cassava bacterial blight disease (CBB) has not been studied extensively in Sierra Leone in terms of yield loss and loss associated with the esthetic value of the marketable leaves. This is important because cassava leaf is highly consumed as a vegetable sauce among millions of people countrywide [14]. An increase in the incidence and severity of cassava bacteria blight will affect the cassava leaf market as well as the livelihood of smallholder farmers especially women.

Cassava anthracnose disease (CAD) and leaf spot disease (LSD) were the least important in terms of threat in cassava production. Higher incidence of cassava anthracnose disease and leaf spot disease recorded in the dry season in Bombali, Port Loko, Kono and Tonkololi remains a concern.

5. Conclusion and recommendation

From the research the following conclusion can be drawn:

Cassava Mosaic Disease (CMD) was considered to be more prominent in the rainy season than the dry season. In district terms, Kono, Koinadugu and Tonkolili districts had the highest incidence and severity of Cassava Mosaic Disease (CMD) in the dry season. Koinadugu, Kenema and Kambia had the highest incidence in the rainy season. Generally, Bonthe and Western Area were among the lowest in terms of incidence and severity of the Cassava Mosaic Disease (CMD). No clear hot spot was identified.

In agroecological terms, the rain forest had the highest incidence and severity of the cassava mosaic disease while the coastal plains and the Peninsular Mountains were among the lowest. Spatial distribution map using the geographic information system mapping revealed that CMD was widely distributed across the country.

Based on the current level of expansion in cassava production in Sierra Leone for use as feed, food and industries, it is recommended that routine and comprehensive standardized surveys of cassava diseases be conducted to determine the epidemiology of the diseases. A multidisciplinary approach has to be adapted and should involve entomologists, agronomists, weed scientists and more related disciplines, this integrated approach could be used to design model for diseases forecast in different agro-ecological zones, and avert indiscriminate use of insecticides in the control of most disease vectors should the need arise.

Cassava bacterial blight disease (CBB) was considered to be more prominent in the rainy season than the dry season. At the district level, Kono, Koinadugu and Tonkolili districts had the highest incidence and severity of cassava bacterial blight disease (CBB) in the dry season. Koinadugu, Kenema and Kambia had the highest incidence in the rainy season. Generally, Bonthe and Western Area were among the lowest in terms of incidence and severity of the disease. No clear hot spot was identified.

In agroecological terms, the rain forest had the highest incidence and severity of the cassava bacterial blight disease while the coastal plains and the Peninsular Mountains were among the lowest. Spatial distribution map using the geographic information system mapping revealed that CBB was widely distributed across the country. Despite the high incidences, severity was considered low. From the study, it is recommended that the search for resistant genotypes and farmer education on disease identification and control should be prioritized.

Cassava anthracnose disease (CAD) and Cassava leaf spot disease was considered to be more prominent in the dry season than the rainy season. However, disease incidence and severity were low and therefore considered cassava diseases of less importance in Sierra Leone.

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