



Prevalence of Cassava (*Manihot esculenta* Crantz) Brown Leaf Spot Disease in the Bono Region of Ghana and Association of Fungi with Leaf Spots

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ABSTRACT

Background: This study determined the incidence, severity and distribution of fungal pathogens associated with cassava (*Manihot esculenta* Crantz) causing brown leaf spot (BLS) disease during the 2021-2023 cropping seasons in five communities each from Sunyani municipality, Sunyani west municipality and Dormaa east district of Bono Region, Ghana.

Methods: During the survey, incidence and severity of BLS were observed in cassava fields across the fifteen communities using a purposive sampling method in the dry and rainy seasons. A simple random method was employed to sample 135 infected cassava plants showing symptoms of BLS for isolation and purification of the putative pathogen. The study subsequently validated Koch's postulates.

Result: A total of 898 pathogenic fungal isolates were extracted and identified as belonging to 15 genera, with two fungal pathogens, belonging to the genera *Colletotrichum* and *Lasiodiplodia* spp., identified as the causative agents of BLS with relative prevalence of 40% and 31.68%, respectively. The rainy season had a significantly higher incidence of BLS (76.87%) than the dry season (18.40%). The rainy season also had a significantly higher severity score (63.02) than the dry season (43.3). The damage index in Sunyani west municipality and Dormaa east district was also significantly ($P < 0.001$) different between the dry and rainy seasons. In the rainy season, more foliar damage occurred at an average of 71.9% than in the dry season, which recorded 8.0%.

Key words: Brown leaf spot, Cassava, *Colletotrichum* spp, Incidence, *Lasiodiplodia* spp.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is grown throughout many countries in sub-Saharan Africa (SSA), providing support for over 500 million people with both food and income (The WIRE, 2020). In Ghana, cassava is the most popular root crop and a major staple crop that contributes about 20.5% to the country's agricultural Gross Domestic Product (Sasu, 2022). In 2020, Ghana produced over 21.8 million metric tons of cassava, which was an increase in volume compared to around 19.4 million metric tons in the previous year (Sasu, 2022). An estimated 200 kg of cassava are consumed annually per person in Ghana and also contribute about 40% of daily food consumption (kcal per capita per day) (Frimpong *et al.*, 2023).

Under marginal soil conditions and in drought-prone areas (50% soil available water holding capacity), cassava can flourish with little or no assistance (Machikowa *et al.*, 2020). Although it is mostly grown for its starchy roots, many parts of Africa also eat the nutrient-dense cassava leaves as vegetables (Spencer and Ezedinma, 2017). The consumable component of the root can also serve as a raw material for the production of many traditional fermented meals, energy products, animal feed, or industrial goods such as bioethanol (Reuben-Kalu *et al.*, 2024). According to Ahmed *et al.* (2025) identified advantages, such as enhanced blood parameters, antioxidant activity and meat quality, are ascribed to the bioactive components, vitamins and minerals present in

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cassava leaf meal. Despite the benefits derived from the crop, the growth of the cassava sub-sector has been hindered by two primary constraints; pests and diseases, leading to low yields (Ortiz, 2006). Diseases like cassava brown streak virus disease (CBSD), Cassava bacterial blight (*Xanthomonas axonopodis* pv. *manihotis*) (CBB) and cassava anthracnose (*Colletotrichum gloeosporioides*) (CAD) are some of the common diseases limiting cassava production (Abaca *et al.*, 2014).

Another disease of cassava is the Brown leaf spot (BLS) disease caused by *Cercosporidium henningsii* Allesch (*C. henningsii*) (Powbunthorn *et al.*, 2012). BLS has

a broad geographical distribution, being found in Africa, Latin America, North America and Asia. It attacks naturally *Manihot esculenta*, *Manihot glaziovii* and *Manihot piauhyensis* Ule (Powell, 1972). It is the most significant fungal disease of cassava and, in Ghana, almost all cassava plants are affected by BLS (Ayesu-Offei and Antwi-Boasiako, 1996). The disease is characterized by large, brown, necrotic spots appearing on older leaves and the infected leaves have a tendency to drop early (Pei *et al.*, 2014). Infection of BLS disease causes leaf chlorosis and extensive defoliation, which in turn result in yield loss of up to 20% (Hillocks and Wydra, 2002).

Production of cassava is a very important and widespread livelihood strategy in Ghana, especially in farming communities in the Bono Region. There is a dearth of information on the incidence and severity of cassava BLS disease during the rainy and dry seasons in Ghana. Knowledge of the incidence, severity and distribution of BLS is important for the deployment of germplasm in the management of these biotic stressors (Sharma *et al.*, 2024). Therefore, the aim of the present study was to determine the incidence and severity of BLS disease of cassava and associated pathogens of the disease in Ghana.

MATERIALS AND METHODS

The study area

The study was carried out in Dormaa East District, Sunyani Municipality and Sunyani West Municipality of the Bono

Region of Ghana from 2021 to 2023. Dormaa east District is found within latitudes 7°08'N and 7°25'N and longitudes 2°35'W and 2°48'W. Sunyani West Municipality is located between latitudes 7°19'N and 7°35'N and longitudes 2°08'W and 2°31'W. Sunyani Municipality lies within latitudes 7°20'N and 7°05'N and longitudes 2°30'W and 2°10'W (Fig 1). All the study areas are located within the forest zone of Ghana (GSS 2014).

Field survey and isolation of pathogen

Two surveys were conducted from 2021 to 2023 to assess the disease incidence and severity associated with cassava in farmers' fields across the selected Municipalities/District in the Bono Region of Ghana. Five communities were selected at random in each of the 3 locations (Sunyani municipality, Sunyani West municipality and Dormaa East District) (Table 1). In each location, three farms were sampled and between 3-8 months' cassava plants showing symptoms of BLS were sampled. BLS was observed at each location using a modified "Z" observational method (Otim-Nape *et al.*, 1998).

A non-probability convenience sampling technique was employed to select farmer's fields, which were further divided into zones and sub-blocks. All infected cassava plants were tagged and 20 cassava leaves were randomly sampled (balloted) at regular intervals in each field for disease severity assessment. A total of forty-five (45) cassava farms were visited in the Municipalities/District under study during the rainy and dry seasons, respectively.

A simple random method was employed to sample a total of 135 infected cassava plants showing symptoms of BLS for isolation and purification of the putative pathogen at the Plant Pathology Laboratory of the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Fumesua in Ghana. Single-spore isolation was carried out on the putative pathogens using a modified procedure described by (Choi *et al.*, 1999).

Table 1: Communities selected from the study areas.

Dormaa East District	Sunyani West Municipality	Sunyani Municipality
Kyeremasu	Bofourkrom	Nwawasua
Wamfie	Kobedi	Kurosua
Asuotiano	Nsoatre	Yawsae
Akontanim	Asuakwaa	Kyiribogya
Dormaa akwamu	Kantro	Benue nkwanata

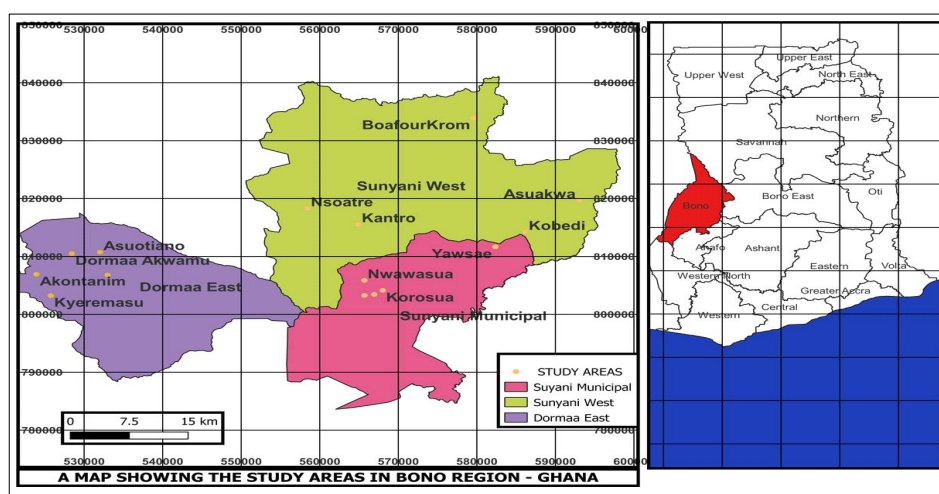


Fig 1: Map of cassava fields surveyed in selected municipalities and a district in the Bono Region.

Morphological and molecular identification

A fresh coverslip was carefully placed on a microscopic slide that contained fungal mycelium and a drop of sterilized water to prevent air bubbles from accessing the fruiting body produced. The state of hyphae-septate or aseptate, branching or non-branching-was examined with a microscope (Optika Microscope Italy Version 2.13) at 40× to study cultural and morphological characteristics.

Using a modified CTAB protocol (Doyle and Doyle 1987), the genomic gDNA of the 7-day-old cultured isolates was extracted. The isolate identification utilized partial gene sequences of two genomic loci: the ribosomal internal transcribed spacer (ITS) and Actin (ACT) genes. The primer pair ACT-512/ACT-783 was used to amplify Actin regions of the isolates (White *et al.* 1990; Carbone and Kohn 1999). The PCR products were electrophoresed in 2% agarose gels in 1X TAE buffer.

Determination of prevalence of BLS

Disease incidence

Disease incidence was assessed on the entire cassava plant in each zone or sub-block. The percentage incidence of the BLS disease was computed as the ratio of the number of cassava plants with the disease symptoms to the total number of cassava plants and multiplied by 100 (Muntala *et al.*, 2020).

Disease incidence (%) =

$$\frac{\text{Number of infected cassava plants}}{\text{Total number of cassava plants}} \times 100$$

Disease severity

BLS severity on the cassava plant as observed in the various communities through physical evaluation was scored by a modified procedure employed by Muntala *et al.* (2020). This was translated by a five -point scale where <1 represented no infection and >75 very high infections (Muntala *et al.*, 2020) (Table 2). In each field, twenty (20) plants were randomly assessed and scored for severity indices. The samples were coded per the name of the locality where they were sampled.

Damage index (DI)

The disease damage index (DI) for each location was calculated according to the formula described by Manandhar *et al.* (2016).

$$DI = \frac{\% \text{ Incidence} \times \text{Severity}}{\text{Highest severity}}$$

Data analysis

Data collected from fungal disease incidence, the severity scores and the damage index were subjected to a two-way analysis of variance using the GenStat statistical package (version 12.1) (Paynes *et al.*, 2009). Differences in means were compared using the Least Significant Differences (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Symptoms and morphological description of the pathogen

The predominant source of yield loss is attributable to diseases induced by fungi, viruses, bacteria and nematodes, which inflict considerable damage and lead to lower yields (Satapathy *et al.*, 2023). Samples of cassava exhibiting noticeable symptoms of the disease (Fig 2 A-B) were selected for the study in order to potentially aid in diagnosis. Cassava plants that appeared to be healthy or asymptomatic (Fig 2 C-D) under normal growing conditions were also sampled. The infected cassava plants exhibited symptoms that included small, dark green spots on both sides of the leaves, which later enlarged, followed by the exhibition of grayish-water-immersion lesions. Finally, these lesions became brown due to disease progression.

Table 2: Disease severity measurement based on 5-point score (0-4 scale).

Scale	Severity score	Interpretation
0	<1	No infection
1	1-25	Low infection
2	26-50	Moderate infection
3	51-75	High infection
4	>75	Very high infection

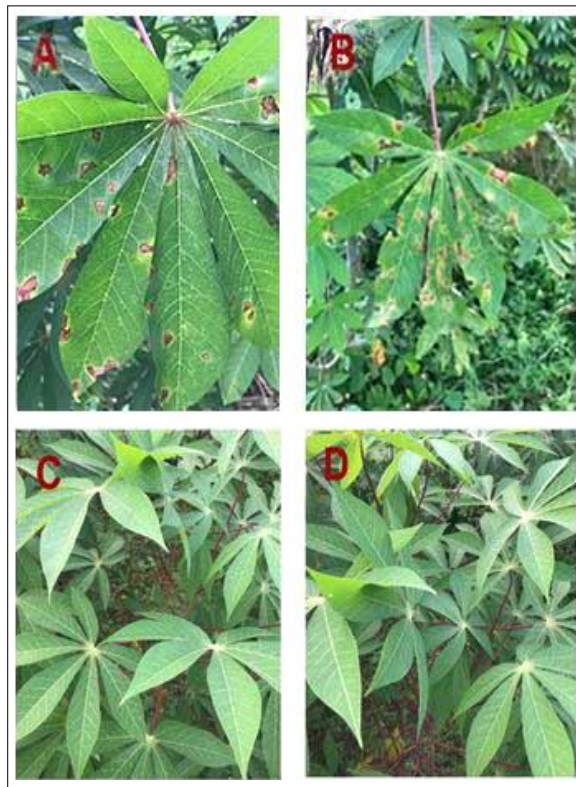


Fig 2: A-B: Cassava leaves showing BLS symptoms, C-D showing healthy cassava leaves.

Typical lesions were characterized by angular, uniform brown spots on both sides of the leaves and the margins of the spots were well defined and dark. In some cases, parts of the small veinlets adjacent to the spots were also dark. Similar finding was reported by (Pei *et al.*, 2014). The centre of some of the disease spots looked dry, cracked and appeared as if it would suddenly fall off. One of the conspicuous signs of the presence of the causal agent of cassava BLS disease is the presence of a yellow halo behind the dark ring band surrounding the necrotic spot (Tsatsia and Jackson, 2018). The fungal pathogen responsible for the BLS disease of cassava in the study area was morphologically and molecularly identified with accession numbers retrieved from GenBank as presented in Table 3.

Disease incidence, severity and damage index

Dry and rainy season disease incidence and average severity in Dormaa East District

In the Dormaa East district, the sample mean results showed incidence (27.62%), severity (42.26) and damage index DI of 10.95 in the dry season, which was low compared to incidence (87.69%), severity (68.57) and DI (87.69) in the rainy season (Table 4). Dormaa Akwamu posted high average disease severities (74.68), (56.73) in the rainy and dry seasons, respectively, with a low dry season incidence (23.60%) and DI (5.90) as compared to the rainy season incidence (88.45%) and (88.45) DI. Wamfie community recorded an incidence of 36.81% with an average severity (48.41), DI (18.41) during the dry

season, while in the rainy season it posted a high DI (90.42) with 90.42% and 82.46, representing disease incidence and severity, respectively. Furthermore, results from Akontanin community had a high incidence (44.01%) and DI (22.01) with disease severity of 32.88 during the dry season, but in the major season, disease incidence increased to 94.24%, Severity and DI increased to 60.41 and 94.24, respectively. The Asuotiano community had a low disease incidence (24.40%), average disease severity (32.06) and a DI (6.10) in the dry season. The trend of results in the rainy season increased, but still posted low disease incidence, severity and DI (78.06%), (55.85) and (78.06), respectively. Results from the Kyeremasu community indicated that the rainy season's incidence (87.28%), severity (69.45) and damage index (87.28) were higher than the incidence (9.28%), DI (2.32) and average disease severity (41.21) in the dry season. Several studies have reported higher incidence of BLS disease in humid environment than in dry one (Oliveira *et al.*, 2018).

Dry and rainy season disease incidence and average severity in Sunyani Municipality

The sample municipal mean results showed mean incidence (7.67%), severity (38.03) and damage index (1.92) to be low in the dry season compared to the results of incidence (54.79%), severity (51.73%) and damage index (40.34%) in the rainy season (Table 5). Comparing the seasons in the respective communities, the Nwawasua community had both incidence and severity being higher during the rainy season, representing 49.49% and 51.60, respectively than incidence (3.57%) and severity (36.89) in the dry season, which was also seen in the Damage Index as the rainy season recorded 24.75% compared to 0.90% in the dry season. Results from the Kurosua community showed similar trends as incidence (9.42%), severity (46.51) and damage index (2.35) were lower in the dry season than incidence (61.91%), severity (57.48) and damage index (46.43) in the rainy season.

Again, in Kyiribogya, it was shown that incidence (15.27%), severity (51.38) and damage index (3.82) were low in the dry season as against incidence (78.21%), severity (54.65) and damage index (78.21) recorded in the rainy season. Furthermore, results from the Yawsae indicated that the rainy season's incidence (62.42%),

Table 3: Detailed information of identified pathogens in this study.

Identified pathogen	Gene name	GenBank accession number
<i>Colletotrichum fructicola</i>	DRM44	PP847209
<i>Colletotrichum siamense</i>	CSNE21	PP847208
<i>Colletotrichum gigasporum</i>	CSNW08	PP847207
<i>Lasiodiplodia theobromae</i>	LSNW44	PP847206
<i>Lasiodiplodia theobromae</i>	LSNY18	PP847204
<i>Lasiodiplodia mediterranea</i>	LDRM28	PP847205
<i>Lasiodiplodia pseudotheobromae</i>	Wamfie	PQ305364
<i>Lasiodiplodia pseudotheobromae</i>	Kyeremasu	PQ305365

Table 4: Disease incidence and average severity in Dormaa East district (Score 0-4 scale).

Community	Dry season			Rainy season		
	Incidence (%)	Severity	DI	Incidence (%)	Severity	DI
Dormaa akwamu	23.60	56.73	5.90	88.45	74.68	88.40
Akontanim	44.01	32.88	22.01	94.24	60.41	94.24
Asuotiano	24.40	32.06	6.10	78.06	55.85	78.06
Wamfie	36.81	48.41	18.41	90.42	82.46	90.42
Kyeremasu	9.28	41.21	2.32	87.28	69.45	87.28
Mean	27.62	42.26	10.95	87.69	68.57	87.60

^aSources: Field data (2022); *DI: Damage index.

severity (53.70) and damage index (46.82) were higher than the dry season's incidence (7.08%), severity (41.48) and damage index (1.77). Lastly, Benue Nkwanta results showed that incidence (21.96%), severity (41.20) and damage index (5.49) were higher in the rainy season than incidence (3.02%), severity (14.00) and damage index (0.75) in the dry season (Table 5).

Dry and rainy season disease incidence and average severity in Sunyani West Municipality

The Sunyani west mean results indicated incidence (19.94%), severity (49.79) and DI (6.96) to be low in the dry season compared to the results of incidence (88.06%), severity (64.81) and DI (88.06) in the rainy season (Table 6). A comparison of seasons within the communities showed that the Kobedi community recorded high disease severity (51.93) in the dry season with low disease incidence and DI of 12.73% and (3.18), respectively compared to the results posted in the rainy season, where disease incidence and DI rose to 79.62% and 79.62 in each instance with disease severity of 60.83. The Bofourkrom community showed similar trends as incidence (23.13%), severity (50.71), DI (5.78) in the dry season were lower than the rainy season, which exhibited high DI, incidence and severity (95.35), (95.35%) and (64.40) in the same order.

Moreover, the results observed in Nsoatre community showed that all indicators were low in the dry season with incidence (39.58%), DI (19.79) and (49.20) disease severity as against incidence (92.35%), severity (69.85) and a DI (92.35) recorded in the rainy season. The trend of results in Asuakwa community maintained high incidence (85.38%), severity (63.60) and disease DI (85.38) in the

rainy season as against low incidence (7.72%) DI (1.93) and (45.58) disease severity in the dry season. In Kantro community, disease incidence of 16.53%, average disease severity of 51.55 and DI of 4.13 were recorded in the dry season. Figures presented had high disease incidence, severity and DI with 87.59%, 65.38 and 87.59, respectively in the rainy season.

Analysis of dry season incidence and severity

The BLS disease incidence among the two Municipalities and the district in the dry season averaged 18.4% with 7.67%, 19.94% and 27.62% in Sunyani municipality, Sunyani West municipality and Dormaa East district, respectively (Table 7). The BLS incidence in Sunyani West Municipality and Dormaa East district did not differ significantly ($P < 0.001$). Sunyani Municipality had a lower incidence than Sunyani West and Dormaa East. The disease severity also differed significantly ($P = 0.025$) among the two Municipalities and a district. It averaged 43.4 and ranged from the least severe 38.04 at Sunyani Municipality to the most severe 49.80 at Sunyani West Municipality. This is in agreement with Samura *et al.* (2021) who reported low incidence of cassava brown leaf spot disease during dry season across all the study locations.

The trend of the results at the community level as assessed showed an average incidence of 18.4% and ranged from the lowest at Benue Nkwanta (3.03%) to the highest at Akontanin (44.01%). The disease severity also averaged 43.3% and ranged from least severe (14.00) at Benue Nkwanta to the most severe (56.73) at Dormaa Akwamu. There were varying degrees of similarities and differences at the community level.

Table 5: Disease incidence and average severity in Sunyani Municipality (Score 0-4 scale).

Towns	Dry season			Rainy season		
	Incidence (%)	Severity	DI	Incidence (%)	Severity	DI
Nwawasua	3.57	36.80	0.90	49.49	51.60	24.75
Kurosua	9.42	46.51	2.35	61.91	57.48	46.43
Kyiribogya	15.27	51.38	3.82	78.21	54.65	78.21
Yawsae	7.08	41.48	1.77	62.42	53.70	46.82
Benue nkwanta	3.02	14.00	0.75	21.96	41.20	5.49
Mean	7.67	38.03	1.92	54.79	51.73	40.34

^bSources: Field data (2022); *DI: Damage index.

Table 6: Disease incidence and average severity in Sunyani West municipality (Score 0-4 scale).

Community	Dry season			Rainy season		
	Incidence (%)	Severity	DI	Incidence (%)	Severity	DI
Asuakwaa	7.72	45.58	1.93	85.38	63.60	85.38
Nsoatre	39.58	49.20	19.79	92.35	69.85	92.35
Kobedi	12.73	51.93	3.18	79.62	60.83	79.62
Bofourkrom	23.13	50.71	5.78	95.35	64.40	95.35
Kantro	16.53	51.55	4.13	87.59	65.38	87.59
Mean	19.94	49.79	6.96	88.06	64.81	88.06

^cSources: Field data (2022); *DI: Damage index.

Analysis of rainy season incidence and severity

BLS disease incidence averaged 76.90%, with Sunyani Municipality having 54.80%, Dormaa East District having 87.69% and Sunyani West Municipality having 88.13% (Table 8) and did not differ significantly at $P < 0.001$ between Sunyani West Municipality and Dormaa East district, but Sunyani Municipality was highly significantly different. Overall, BLS incidence was significantly higher in the rainy season (Table 8) than in the dry season (Table 7). Sunyani Municipality recorded the lowest severity of 51.73, which was significantly different from both Dormaa East district and Sunyani West Municipality with 68.57 and 68.77, respectively. The average severity was 63.00. It is certain from the figures posted that the rainy period recorded a higher severity score than the dry period. The Benue Nkwanta community posted the least incidence (21.97%) and severity (41.20), while Bofourkrom had the highest incidence (95.36%) and severity (84.41), with a grand

average of 76.87% and 63.02 for incidence and severity, respectively. It is certain from the figures posted that in the rainy period, disease intensity was more severe than in the dry period and was at variance with Samura *et al.* (2021), who stated that cassava anthracnose disease (CAD) and cassava leaf spot disease were considered to be more prominent in the dry season than in the rainy season. However, disease incidence and severity were low and, therefore, considered both anthracnose disease (CAD) and brown leaf spot disease of cassava of less importance.

Analysis of damage index in dry and rainy seasons

Table 9 shows damage index of BLS in the two Municipalities and a district in the dry season of an average of 8.00 and differed significantly ($P < 0.001$) among the locations. The lowest damage in the dry season occurred in Sunyani Municipality (2.37), Sunyani West Municipality (8.31) and the highest damage occurred in Dormaa East (13.29). In the rainy season, more foliar damage occurred in Sunyani West Municipality (88.13), Dormaa East district (86.47) and were not significantly different from each other at $P < 0.001$. Sunyani Municipality had the lowest foliar damage (41.21) and was significantly lower than the other two locations, with an average of 71.90. The lowest and highest foliar damages at the community level occurred between Benue Nkwanta (0.75) and Akontanim (30.177), averaging 8.00 in the dry season, while in the rainy season more damage occurred in Benue Nkwanta (5.49) and Bofourkrom (95.36) at an average of 71.94 ($P < 0.001$). Damage indices between the dry and rainy seasons were highly significantly different. It is therefore important to note that, BLS has not been well studied in terms of yield loss and losses associated with the esthetic value of the marketable leaves. This is critical because cassava leaf is highly consumed as a vegetable sauce among millions of people worldwide (Oliveira *et al.*, 2018). An increase in the incidence and severity of cassava BLS can affect the cassava leaf market value as well as the livelihood of smallholder farmers, especially women.

Major fungal pathogens associated with cassava brown leaf spot disease

Fungal isolations realized on cassava leaf samples from the forty-five (45) locations revealed a great diversity of species associated with cassava BLS disease. In all, 898 fungal isolates, representing 15 different genera were grouped. *Colletotrichum* spp. and *Lasiodiplodia* spp. were the most common genera with 40% and 31.68% relative prevalence (Fig 3). Other pathogens such as *Fusarium* spp., *Verticillium* spp. and *Sclerotia* spp. with 9.13%, 0.33% and 0.11%, respectively were recorded. Leaf spot-forming pathogens realized were *Pestalotia* spp. (6.24%), *Cladosporium* spp. (3.34%), *Curvularia* spp. (0.78%), *Alternaria* (1.22%) and *Melanosporium* spp. (0.22%). Non-pathogenic organisms isolated were *Neurospora* spp. (2.78%), *Aspergillus* spp. (1.89%), *Penicillium* spp. (1.11%), *Rhizopus* spp. (0.67%) and *Trichoderma* spp. (0.56%).

Table 7: BLS incidence and severity of cassava in MMDA/ communities in the dry season.

MMDA/Community	Disease incidence (%)	Disease severity
Sunyani Municipal	7.67 ^a	38.04 ^a
Sunyani West Municipal	19.94 ^b	49.80 ^b
Dormaa East District	27.62 ^b	42.27 ^{ab}
Grand mean	18.4	43.40
CV%	75.9	26.50
S.E.D	5.10	4.20
P-value	<0.001	0.025
Benue nkwanta	3.02 ^a	14.00 ^a
Nwawasua	3.57 ^a	36.80 ^{bc}
Yawsae	7.08 ^{ab}	41.48 ^{bcd}
Asuakwa	7.73 ^{ab}	45.58 ^{cde}
Kyeremasu	9.28 ^{ab}	41.24 ^{bcd}
Kurosua	9.42 ^{ab}	46.52 ^{cde}
Kobedi	12.73 ^{ab}	51.93 ^{de}
Kyiribogya	15.27 ^{ab}	51.38 ^{de}
Kantro	16.53 ^{ab}	51.55 ^{de}
Bofourkrom	23.13 ^{bc}	50.72 ^{de}
Dormaa akwamu	23.60 ^{bc}	56.73 ^e
Asuotiano	24.40 ^{bc}	32.07 ^b
Wamfie	36.81 ^{cd}	48.42 ^{cde}
Nsoatre	39.58 ^{cd}	49.20 ^{de}
Akontanim	44.01 ^d	32.88 ^b
Grand mean	18.4	43.3
CV (%)	62.2	17.1
S.E.D (5%)	9.34	6.04
P-value	<0.001	<0.001

^aSources: Field data (2022); ^NMMDA: Metropolitan, Municipal and District Assembly; ^NLetter a-z: Ranking; CV: Coefficient of variation; SED: Standard error of the differences of means; means in the same column with similar letters are not significantly different from each other ($P < 0.001$).

Table 8: BLS incidence and severity of cassava in MMDA/communities in the rainy season.

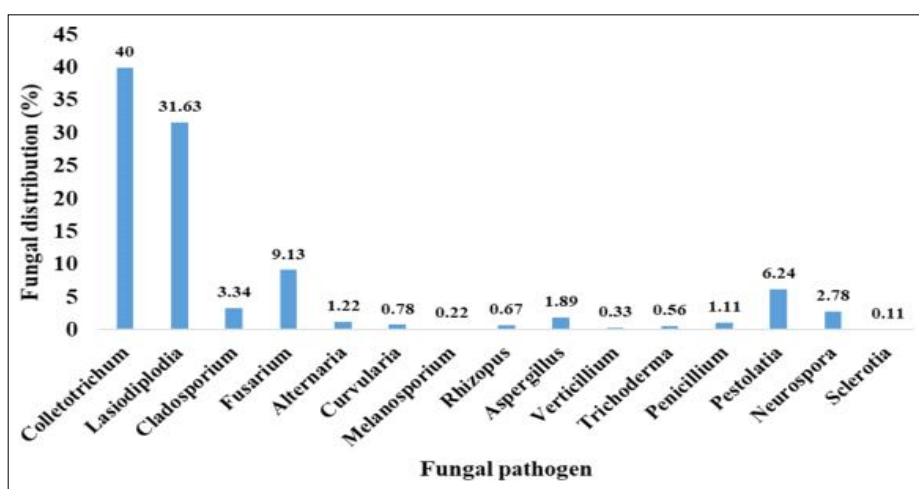
MMDA/Community	Disease incidence (%)	Disease severity
Sunyani East Municipal	54.80 ^a	51.73 ^a
Dormaa East	87.69 ^b	68.57 ^b
Sunyani West Municipal	88.13 ^b	68.77 ^b
Grand mean	76.9	63.0
CV%	16.5	15.4
S.E.D	4.64	3.55
P-value	<0.001	<0.001
Benue nkwanta	21.97	41.20 ^a
Nwawasua	49.49	51.60 ^b
Kurosua	61.91 ^a	57.48 ^{bcd}
Yawsae	62.42 ^a	53.70 ^{bc}
Asuotiano	78.06 ^b	55.85 ^{bcd}
Kyribogya	78.21 ^b	54.65 ^{bc}
Kobedi	79.62 ^b	60.83 ^{bcd}
Asuakwa	85.38 ^{bc}	63.60 ^{cde}
Kyeremasu	87.28 ^{cd}	69.45 ^{ef}
Kantro	87.93 ^{cde}	65.38 ^{def}
Dormaa akwamu	88.45 ^{cde}	74.68 ^{fg}
Wamfie	90.42 ^{cde}	82.46 ^g
Nsoatre	92.35 ^{cde}	69.65 ^{ef}
Akontanim	94.24 ^{de}	60.42 ^{bcd}
Bofourkrom	95.36 ^e	84.41 ^g
Grand mean	76.87	63.02
CV (%)	5.90	9.50
S.E.D (5%)	3.67	4.88
P-value	<0.001	<0.001

^aSources: Field data (2022); ^NMMDA: Metropolitan, Municipal and District Assembly; ^NLetter a-z: Ranking; CV: Coefficient of variation; SED: Standard error of the differences of means; means in the same column with similar letters are not significantly different from each other (P<0.001).

Fungal pathogens isolated in each community

This study has brought forth the diversity of organisms in different locations within the study area after isolation. The study showed the causative agents of the disease in Dormaa Akwamu to be *Colletotrichum* spp. (32.93%), *Lasiodiplodia* spp. (32.93%), *Pestalotia* and *Fusarium* spp. (10.98%) each, *Cladosporium* and *Aspergillus* spp. (3.66%) each, *Alternaria*, *Curvularia*, *Verticillium* and *Rhizopus* each had 1.22%. In the Akontanim, the predominant fungal pathogens set apart were *Colletotrichum* and *Lasiodiplodia* spp. (26.47%) each, *Fusarium* spp. (14.71%), *Pestalotia* spp. (9.80%), *Aspergillus* spp. (7.84%), *Cladosporium* spp. (6.86%), *Rhizopus* spp. (2.94%), *Neurospora* spp. (1.96%), while *Curvularia*, *Verticillium* and *Trichoderma* spp. had 0.98% each. For Asuotiano, both *Colletotrichum* and *Lasiodiplodia* spp. had 35.53% each of the total fungal pathogens isolated, *Fusarium* spp. accounted for 14.47%, *Pestalotia* spp. had 11.84% with *Aspergillus* and *Neurospora* spp. having (1.32%) each. Pathogens realized from isolation in Wamfie were *Colletotrichum* spp. (33.93%), *Lasiodiplodia* spp. (33.93%), *Pestalotia* spp. (9.98%), *Fusarium* spp. (7.54%) and the total isolates of *Neurospora* spp. was 14.63. *Colletotrichum* and *Lasiodiplodia* spp. accounted for 35.06% points each of all BLS pathogens in Kyeremasu, 11.69% was attributed to *Neurospora* spp., 9.10% to *Pestalotia*, *Fusarium* spp. (7.79%) and *Trichoderma* spp. contributed 1.30% point.

In Asuakwa, the majority of the fungal pathogens were *Colletotrichum* and *Lasiodiplodia* spp. with both producing 31.03% each of all isolates, *Fusarium* spp. was next with 16.37%, *Cladosporium* spp. followed with 9.70% *Penicillium* and *Pestalotia* spp. had 7.03% and 4.37%, respectively. *Colletotrichum* spp. had the highest occurrence in Nsoatre with 39.53%, followed by *Lasiodiplodia* spp. (32.56%) with *Cladosporium*, *Fusarium* and *Pestalotia* spp. each contributing 6.98% of the total pathogens. *Rhizopus*, *Aspergillus* and *Penicillium* spp.

**Fig 3:** Relative prevalence of fungal species associated with BLS.

produced 2.33% each. Fungi of the genera *Colletotrichum* spp. were the most encountered in Kobedi with 42.86%, followed by *Lasiodiplodia* spp. reporting 31.43%, while *Cladosporium* and *Pestalotia* spp. had 11.43% with

Table 9: BLS Damage index of cassava in the dry and rainy season.

MMDA/Community	Dry season	Rainy season
Sunyani East Municipal	2.37 ^a	41.21 ^a
Sunyani West Municipal	8.31 ^{ab}	86.47 ^b
Dormaa East	13.29 ^b	88.13 ^b
Grand mean	8.0	71.9
CV (%)	132.7	22.5
S.E. D (5%)	3.87	5.91
P-value	<0.001	<0.001
Benue nkwantu	0.75	5.49
Nwawasua	0.89 ^a	29.18
Yawsae	1.76 ^{ab}	46.72 ^a
Asuakwa	1.93 ^{ab}	85.38 ^{bcd}
Kyeremasu	2.31 ^{abc}	87.28 ^{bcd}
Kurosua	2.35 ^{abc}	46.43 ^a
Kobedi	3.18 ^{abc}	79.62 ^{bcd}
Kantro	4.12 ^{abc}	87.92 ^{bcd}
Kyiribogya	6.10 ^{abc}	78.21 ^{bc}
Dormaa akwamu	8.49 ^{abc}	88.45 ^{de}
Asuotiano	8.87 ^{abc}	71.98 ^b
Bofourkrom	14.68 ^{abcd}	95.36 ^e
Wamfie	16.60 ^{bcd}	90.42 ^e
Nsoatre	17.63 ^{cd}	92.35 ^e
Akontanim	30.17 ^d	94.24 ^e
Grand mean	8.00	71.94
CV (%)	117.6	8.50
S.E.D (5%)	7.67	5.00
P-value	0.022	<0.001

^aSources: Field data (2022); ^NMMDA: Metropolitan, Municipal and District Assembly; ^NLetter a-z: Ranking; CV: Coefficient of variation; SED: Standard error of the differences of means; means in the same column with similar letters are not significantly different from each other ($P < 0.001$).

Fusarium spp. posting 2.86% of all isolates in that location. With a relative occurrence in terms of isolation frequency of 39.02% for *Colletotrichum* spp. which was the highest in Bofourkrom, 31.71% for *Lasiodiplodia* spp., 24.39% was produced by *Fusarium* spp. *Cladosporium* spp. was the least with 4.88%. Kantro produced the least fungal pathogens in the entire study with *Colletotrichum* and *Lasiodiplodia* spp. all producing 47.83% in each case, while *Cladosporium* sp. contributed 4.35%.

The dominant fungi species identified in Nwawasua was *Colletotrichum* spp. with 71.05% of all isolates, *Lasiodiplodia* spp. had 10.53% of the total species isolated. *Curvularia* spp. and *Aspergillus* spp. had 5.26% each, while *Fusarium*, *Trichoderma* and *Penicillium* spp. produced 2.63% each. In Kurosua, *Colletotrichum* spp. was the highest (52%), followed by *Lasiodiplodia* spp. (38.00%) and *Neurospora* spp. with (4.00%), while *Cladosporium* spp., *Fusarium* spp. and *Melanosporium* spp. all produced 2.00% each. The main fungal pathogen of BLS in Kyiribogya was *Colletotrichum* spp. (52.08%), followed by *Lasiodiplodia* spp. (29.17%) and *Cladosporium* and *Pestalotia* spp. (4.17%) each. The least were *Fusarium*, *Curvularia*, *Aspergillus*, *Penicillium* and *Sclerotia* spp. all with (2.08%) each. In Yawsae, *Colletotrichum* spp. was 51.92%, followed by *Lasiodiplodia* spp. (32.69%), *Fusarium* spp. (7.69%), *Penicillium* spp. (3.85%). *Cladosporium* and *Trichoderma* spp. were the least with 1.92% in each case. The majority of isolates in Benue Nkwanta were *Colletotrichum* spp. (56.25%), *Lasiodiplodia* spp. (27.08%), *Fusarium* spp. (6.25%) and *Curvularia* spp. (4.17%), while *Cladosporium*, *Penicillium* and *Trichoderma* spp. all produced 2.08% each.

Fungal pathogens isolated in the, Municipal and District Assembly (MDA)

In Dormaa East District, Akontanim recorded the highest fungal pathogens (24.34%), with Dormaa Akwamu and Wamfie posting 19.57% each. Kyeremasu had 18.34% of phytopathogens, whereas the least was reported in Asuotiano (18.14%) (Fig 4). The results presented in Fig 5. revealed that Yawsae exhibited the maximum fungal

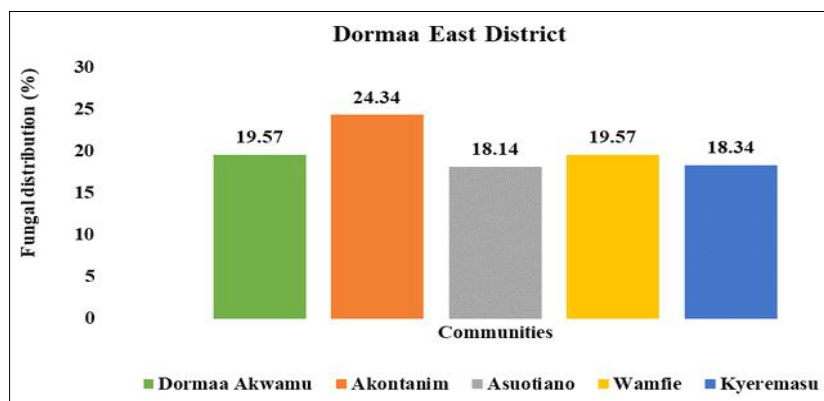


Fig 4: Fungal pathogens identified in Dormaa East District.

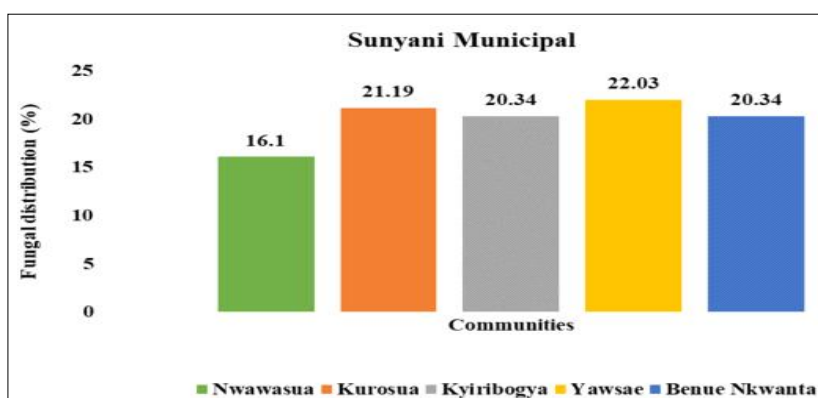


Fig 5: Fungal pathogens identified in Sunyani Municipality.

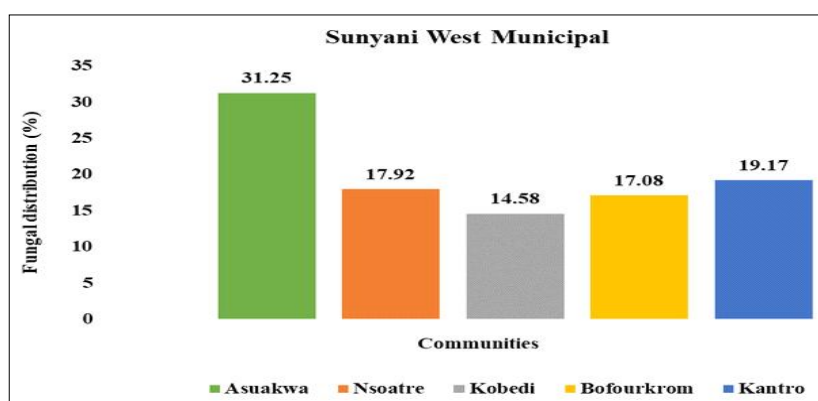


Fig 6: Fungal pathogens identified in Sunyani West Municipality.

pathogens associated with BLS of cassava in Sunyani municipality with 22.03% points. This was followed by Kurosua (21.19%), with both Kyiribogya and Benue Nkwanta reporting 20.34% each. Nwawasua had 16.10%, which was the lowest in the Municipality. Kobedi posted the lowest pathogens (14.45%), while Asuakwa had the highest pathogens on cassava (31.25%) in Sunyani West District. Kantro also had (19.17%), Nsoatre (17.92%) and Bofourkrom (17.08%) of all fungal pathogens identified in this district (Fig 6).

CONCLUSION

Cassava brown leaf spot disease was prevalent in the area surveyed. In all the three study areas, the disease incidence varied considerably. In the cassava fields, cassava plants displayed incredibly severe symptoms of brown leaf spot, which increased concerns about significant crop losses. Therefore, to guarantee the implementation of appropriate disease management measures and to successfully increase crop yields, it is imperative to perform routine inspection and monitoring of cassava brown leaf spot disease in the study areas.

Conflict of interest

All authors declare that they have no conflicts of interests.

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