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INCIDENCE OF COCOYAM (*COLOCASIAE ESCULENTA* (L) SCHOTT) LEAF BLIGHT IN NORTH CENTRAL NIGERIA

Pandukur, S. G*[1]., Zarafi, A. B[2]., Alao S.E. L[2]. and Adekpe, D.I[3]
[1]Department of Science Laboratory Technology, Faculty of Natural Sciences, University of Jos, Plateau State and [2]Department of Crop Protection, [3]Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University, Zaria, Kaduna State.
***Corresponding Author Email:** garbap@unijos.edu.ng **Mobile number: +234-08037698677**

SUMMARY
Cocoyam (*Colocasiae esculenta* (L) Schott), a member of the *Araceae* family is a staple food in many developing countries in Africa, Asia and the Pacific Island. It is produced mainly in Africa but its production is constrained mainly by cocoyam leaf blight (CLB) disease. The disease causes destruction of leaf and corm. Knowledge pertaining to CLB disease incidence in farmers' fields in North Central Nigeria is limited. *A survey of cocoyam in farmers' fields was carried out in three North Central States in 2019 and 2021 rainy season.* The highest disease incidence *under natural infection in farmers' fields during rainy season in the three States* was recorded in 2019 in Barkin Ladi Local Government Area (LGA) (92.07%) of Plateau State while the lowest was recorded in Akwanga LGA (80.15%) of Nasarawa State. The highest and lowest disease incidence recorded in 2021 were in Buruku and Logo LGAs with (88.65%) and (81.16%) both in Benue State respectively. This indicated high level of infection/prevalence of the diseases in the study areas. Overall, there was no significant difference ($p \leq 0.05$) in the disease incidences and the interactions between years, communities, LGA and states. The high incidences of this disease present a threat to the production of cocoyam in the study areas. Keeping in view the importance of cocoyam and losses caused by cocoyam leaf blight pathogen, preventive disease control strategies should be adopted to combat and check the epidemic in the study areas, Nigeria and beyond since blight disease, when present, spreads at a faster rate. This can be made possible through further molecular characterization of the *Phytophthora* spp. that will ascertain variability within the causal pathogen.

Keywords: Incidence, *Phytophthora* spp., **Cocoyam Leaf blight,** North-Central Nigeria.

Cocoyam (*Colocasiae esculenta* (L) Schott) is an orphan crop with potentials to ameliorate malnutrition and food scarcity in developing nations and a major staple food for more than 400 million people in both rural and urban areas of the tropics and sub-tropics (5;24;4). It is the 14th most consumed vegetable and the fifth most harvested root crop in the world.

Cocoyam has a better adaptation to saline and swampy soils than other related crops such as cassava and potatoes. It is a rich source of carbohydrates (14-23%), proteins (0.3-4.8%), the leaves are rich sources of vitamin B6, vitamin C, niacin, thiamin, riboflavin and minerals (23;26). The high carbohydrate content shows that the crop is superior compared to other tubers like sweet potatoes and cassava based on its proximate nutritional composition (25). The corms are utilized as an industrial raw material for the preparation of high fructose, syrup, alcohol and drugs. This has resulted in its' high demand as staple food crop.

Nigeria, the highest producer of cocoyam globally, produced 3.3 and 2.86 million metric tonnes in 2014 and 2021 respectively, making 27.14% of total world production in 2021 (13;14).

Despite these numerous socioeconomic benefits of cocoyam plant, its production and yield continues to decline yearly due to high cost of propagation, shortage in planting material, lack of sustained funding by government institutions, abiotic and biotic factors such as diseases induced by fungi, bacteria, nematodes, and viruses (12). Prominent among these diseases is leaf blight caused by *Phytophthora colocasiae* Racib (38;30;45).

Cocoyam leaf blight (CLB) was *first reported in Africa (Nigeria, Ghana and Equatorial Guinea)* (49;28;33a). Infected leaves initially show small dark spots which enlarge and coalesce rapidly into purplish brown with yellowish margins lesions/blights with concentric zones and yellowish liquid exudes. Diseased tissues disintegrate, forming holes of irregular size and shape on the affected leaves (3).

There is dearth of information on the incidence and severity of cocoyam leaf blight in West African countries and some parts of North Central States Nigeria. Thus, there is need to properly document the incidence and severity of the disease so as to develop both short- and long-term management strategies for the disease. A report from the preliminary survey suggests that the disease could be spreading to the areas of no disease incidence and similar agro-ecological zones within Nigeria (35).

The numerous reports of the incidences and severities of CLB from other researchers and crop protectionists, the deployment of any control measure for managing the aforementioned challenges will however depend on proper quantification or surveys on the disease incidence in North-Central Nigeria as well as specific identification of the causative agent microscopically and molecularly.

MATERIALS AND METHODS

Study area and survey

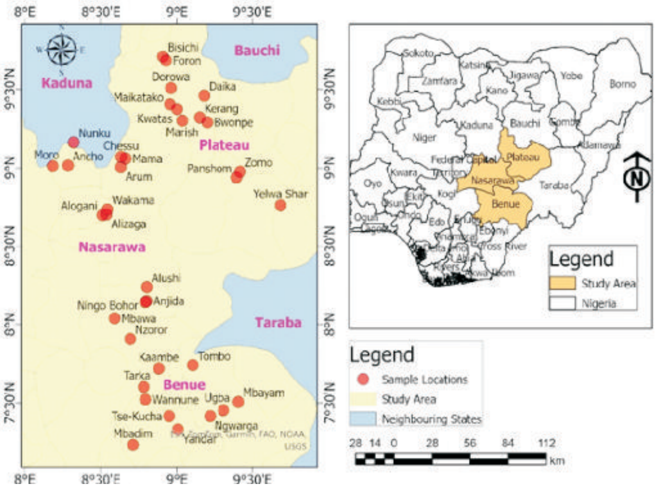

Figure 1: Distribution of cocoyam leaf blight incidences from surveyed areas according to communities in North Central Nigeria

Two surveys were conducted during the vegetative stage (July-November) in *2019 and 2021 in* three cocoyam-growing agro-ecological regions/states (Benue, Nasarawa and Plateau) *within the North Central Nigeria in wet season to determine the incidence and the severity of cocoyam leaf blight (CLB) in farmers' fields.* Healthy cocoyam plant leaves and petioles showing symptoms of blight were collected. In each State, four (4) Local Government Areas (LGAs), three (3) cocoyam farming communities per LGA and four (4) fields/farms each per community were visited and, in each farm, a diagonal pattern was made by measuring 4m x 4m (mini plot) by a square marked out and pegged. The number of plants with symptoms of the disease was counted at random and recorded from each mini plot. Disease incidence was determined as the ratio of the number of plants infected with disease or symptoms to the total number of plants assessed and expressed as a percentage while disease severity was expressed on a modified quantitative disease severity scale of 1-6 according to modified scale by Zarafi *et al*. (49) where: **1** = No disease/symptoms; **2** = 1-25 % leaves and 1-20 % petioles blighted: **3** = 26-50 % leaves and 21 - 40 % petioles blighted; ***4*** = 51-75 % leaves, 41 - 60 % petioles blighted, **5** = 76-90 % leaves and 61 – 80 % petioles blighted; ***6*** = Over 91 % leaves, 81–100 % collapse of petiole accompanied by complete leaf blight or plant completely destroyed.

$$\text{Percentage Blight Incidence (PBI)} = \frac{\text{number of infested plants (Nip)}}{\text{Total number of plants examined (TnpE)}} \times 100$$

Diseased leaf samples were collected in labelled paper bags during field survey and taken to the l**aboratory** for further study**.**

Isolation and identification of fungi associated with cocoyam leaf blight

Carrot Potato Agar medium (**CPA**) **[(**Carrot: 150g, Peeled potato slices: 50g**,** Dextrose: 20g, Agar agar: 20g**,** Distilled water: 1000 ml)] was prepared according to the manufacturer's instructions with slight modification according to Padmaja *et al.* (33a) and a modern analytical isolation technique (Hyphal Tipping) was used. The diseased leaf samples collected were washed with tap water and cut with a blade into 2 cm × 2 cm pieces at the interface between healthy and infected portions. The pieces were surface sterilized in 40% absolute alcohol for 1 minute and 2 minutes in 1% sodium hypochlorite, rinsed in three changes of sterile distilled water (SDW), blotted dry with Whatman paper to get dry. The pieces were plated in Petri dishes with CPA medium amended with 100 mg tetracycline, 100 mg ampicillin and 10 mg rifampicin and incubated at optimum temperature (23±2 ^{0}C) and observed daily for mycelial growth and sporulation. Representative cultures or pure cultures were obtained by sub-culturing onto freshly prepared solidified CPA. Isolated organisms were observed and photographed using an Olympus BX53F microscope (Olympus) equipped with a DigiRetina 16 M digital camera at (×40) and identified based on their morphological characters using standard mycological keys and manual descriptors (47; 48; 40;17;46).

STATISTICAL ANALYSIS

Data generated from the survey and laboratory experiment were subjected to Analysis of Variance (ANOVA) and the significant means were compared using Fisher's least significant difference (LSD) at 5% probability level (27) and Statistical Analysis System Institute inc. version 8.3 (36) .

RESULTS

Disease incidence of cocoyam leaf blight in three North Central States (Benue, Nasarawa and Plateau State in 2019 and

2021)

The highest disease incidence (92.07%) recorded in 2019 was in Barkin Ladi LGA followed by Mangu LGA of Plateau State while the least (80.15%) was recorded in Akwanga LGA of Nasarawa State (Fig. 2). In 2021, the highest (88.65%) and the lowest (81.16%) disease incidence were both recorded in Buruku and Logo LGAs both of Benue State (Fig. 3). Mangu LGA also recorded the second highest disease incidence in 2021 after Buruku LGA (87.18%) (Fig.3). Overall, the results showed that there was no significant ($p \leq 0.05$) difference among the disease incidence observed across the LGAs and the years. However, 2019 had the highest-ranking disease incidence than 2021 during rainy seasons.

The Interactive Effects of years, States, LGA and communities on Disease incidence and severity in North Central Nigeria in the 2019 and 2021

The summary and five level of interactive effects of Year; State; LGA; Community on leaf blight incidences and severities in Benue, Nasarawa and Plateau States across the twelve communities were shown in (Table 1). The disease incidence in the twelve local government areas from the three States during 2019 and 2021 wet season survey recorded 84.07% and 85.36% respectively across the LGAs which statically did not vary significantly ($p \leq 0.05 = 0.83$) in both years (interactions in 2019 and 2021) (Table 1). Overall, the results of the interaction between Years × LGAs, Years × LGA × community and Years × States × Communities showed that they were all significant ($p > 0.05$) during 2019 and 2021 surveys in farmer's fields.

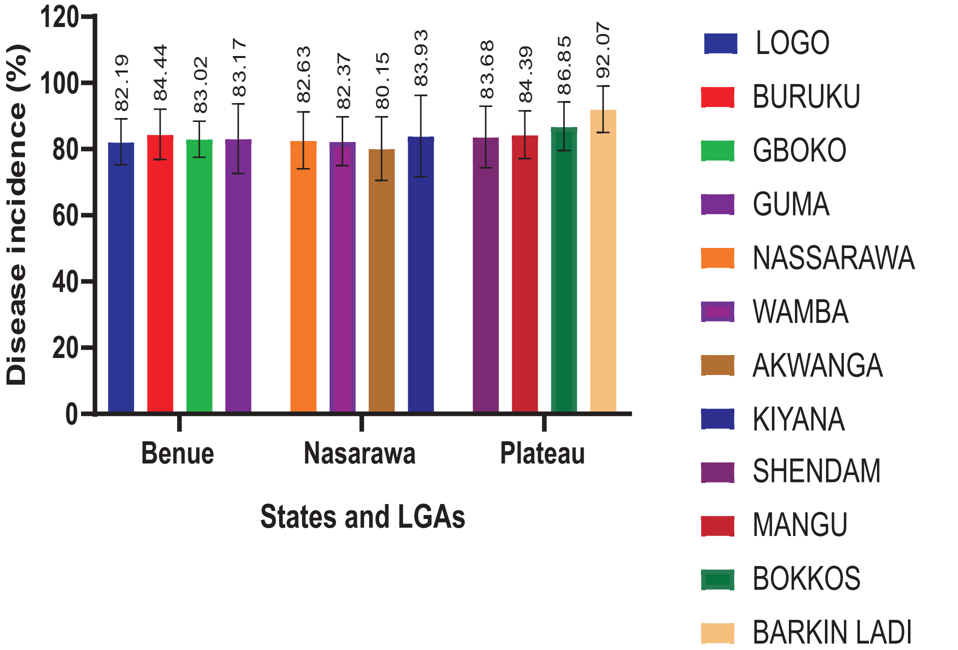

Figure 2: Disease Incidences of CLB in the three States from North-Central Nigeria during 2019 wet season survey

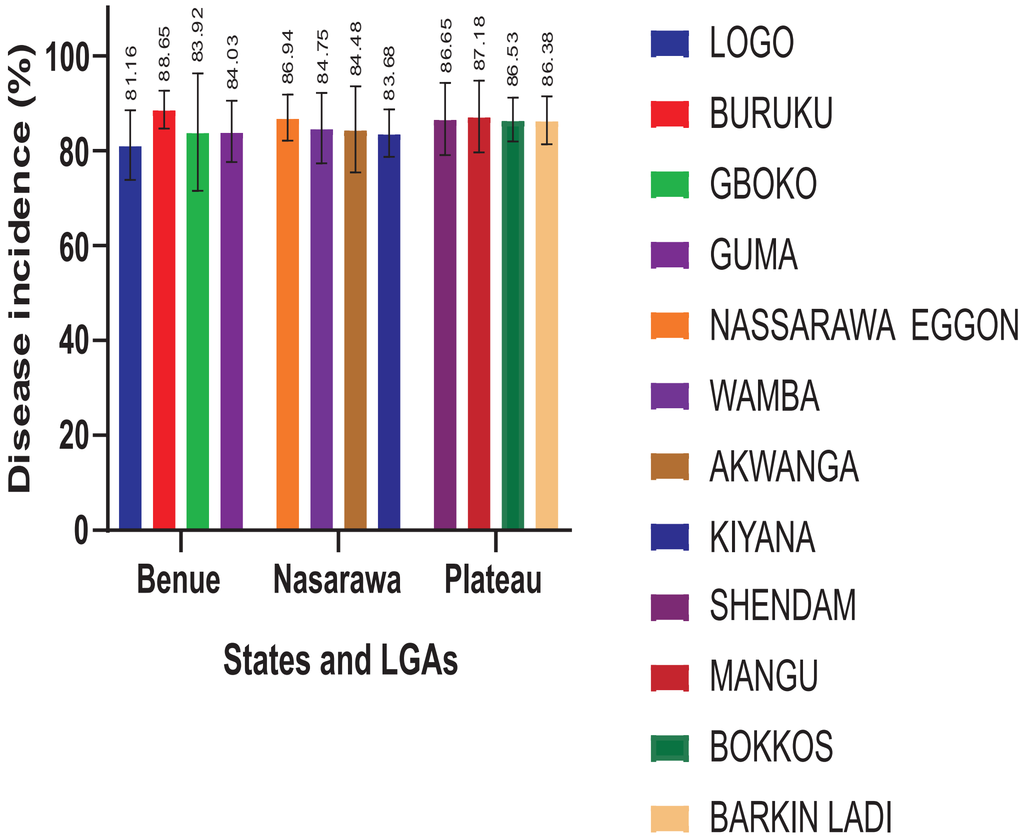

Figure 3: Disease Incidence of TLB in the three States from North-Central Nigeria in 2021

Table 1: Interactive effect of the disease Incidence of cocoyam leaf blight in twelve LGAs of the three states (Benue, Nasarawa and Plateau) during 2019 and 2021 wet season survey

L.G.A(s)/ Year(s)	Incidence (%) 2019	State	Incidence (%) 2021
		Benue	
Logo	82.19^{a}		81.16^{c}
Gboko	83.03a		83.92^{b}
Guma	83.17a		84.03^{b}
Buruku	84.44^{a}		88.65^{a}
SE±	**4.95**		**1.43**
		Nasarawa	
Nasarawa-Eggon	82.63^{a}		86.94^{a}
Wamba	82.37^{a}		84.75^{a}
Akwanga	80.15^{a}		84.48^{a}
Kiyana	83.93^{a}		83.68^{a}
SE±	**5.09**		**2.43**
		Plateau	
Shendam	83.68^{c}		86.65^{a}
Mangu	84.39^{c}		87.18a
Barkin-Ladi	92.07^{a}		86.38a
Bokkos	86.85^{b}		86.53a
SE±	**5.30**		**2.15**
Interaction(s)			
Years	84.07		
2019	85.36		
2021	**0.83**		
SE±			
	*		*
Years × LGAs	*		*
	*		*
Years × LGAs ×Com			
Years × States × Com			

Means followed by the same letter (s) in a column are not significantly ($p \leq 0.05$) different* = Significant using the students' Newman Keul (SNK) . LGA = Local Government Area, NS = Not significant, * = Significant

Table 2: Frequency of occurre nce of fungi isolates across three states (Benue, Nasarawa and Plateau States) Isolated from the Diseased Cocoyam plants from farmer's fields

S/No.	Fungi Isolates	No. of times isolated/Frequency	Percentage (%) Occurrence
1	*Curvularia* spp	15	16.13
2	*Aspergillus terrus*	10	10.75
3	*Fusarium oxysporum*	15	16.13
4	*Cladosporium* spp.	11	11.83
5	*Phythium* spp	11	11.83
6	*Alternaria alternata*	10	10.75
7	*Phytophthora* spp.	21	22.58
	Total	88	100%

Plate. 1(a) (b)

Plate 1: (a & b) Typical advancing cocoyam leaf blight symptoms on naturally infected cocoyam plant from the farmers' field.

Plates 2-7: Macrographs of isolated fungi from cocoyam leaf on Carrot Potato Agar plates and their micrographic view Plate 2: *Aspergillus terrus, Plate 3: Fusarium oxysporum,* Plate 4: *Alternaria alternate,* Plate 5: *Phytophthora* spp, *Plate 6: Curvularia spp. and Plate 7: Cladosporium spp.*

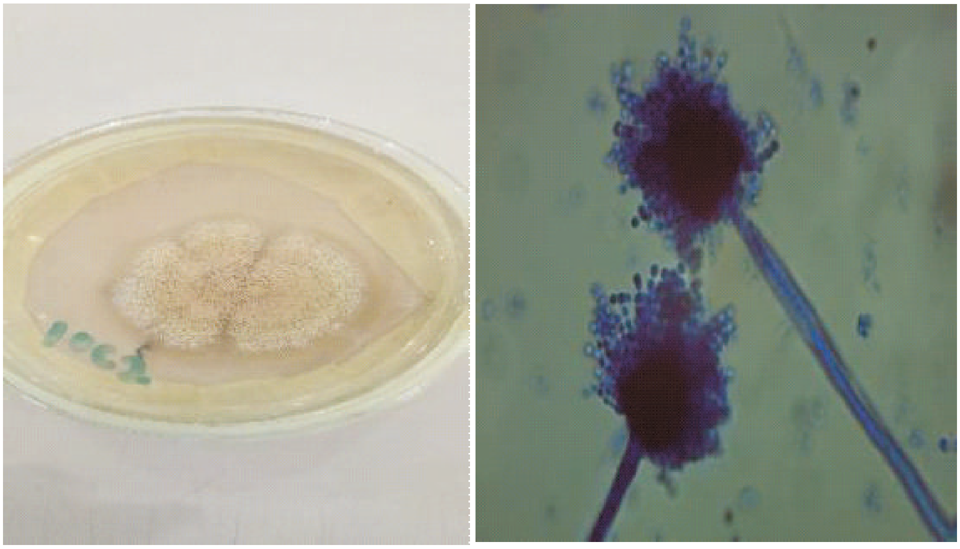

Plate. 2. Macro and micrograph of fungal isolate: *Aspergillus terrus* four days after inoculation in plate PDA plate (x400 magnification).

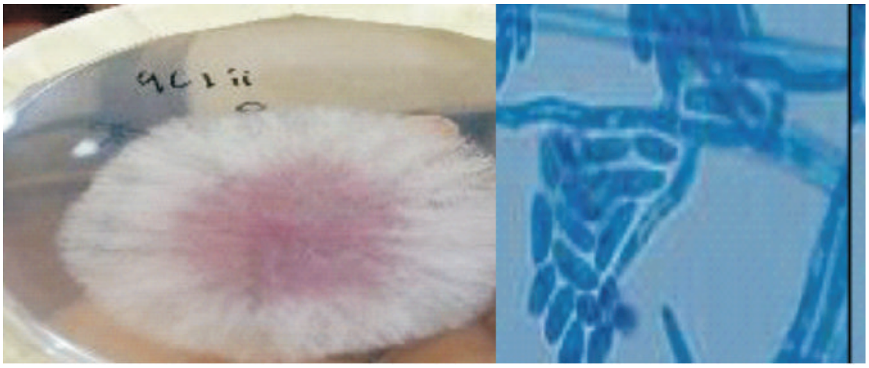

Plate 3. Macro and Microscopic view of *Fusarium oxysporum* four days after inoculation and (x400 magnification) respectively.

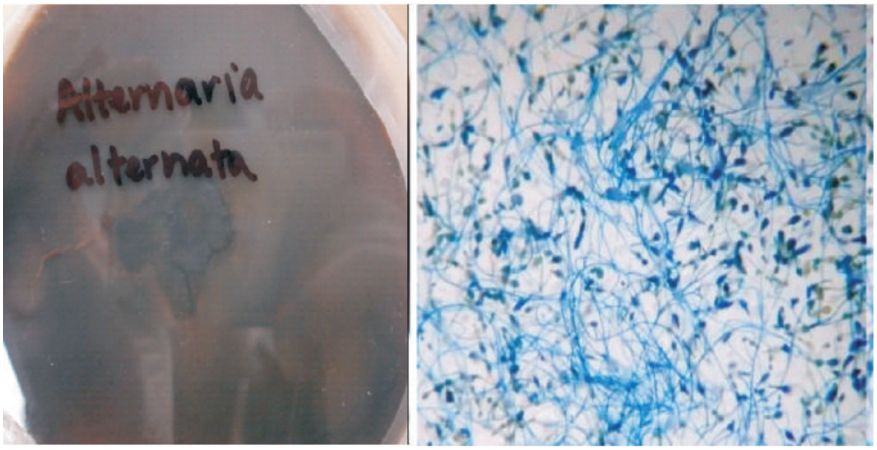

Plate 4. Growth of *A. alternata* seven days after inoculation in plate CPA plate and microscopic view at x400 magnification.

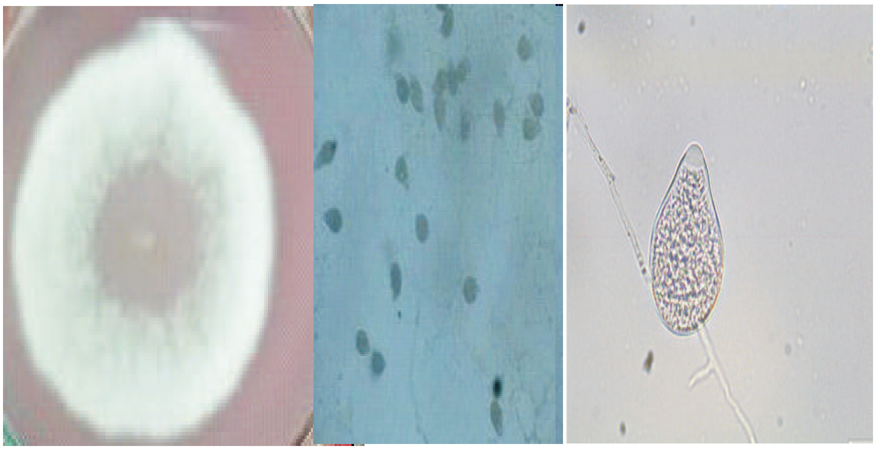

Plate 5: a, b & c: Circular, white and dull-white colonies with cottony sparse and dense mycelial growth patterns of *Phytophthora spp. isolates* in the CPA agar four days after inoculation (b, c) Ovoid sporangial (Magnification: 100×) micrograph of single sporangium spore of *Phytophthora* spp. (Scale bar = 10 μm) .

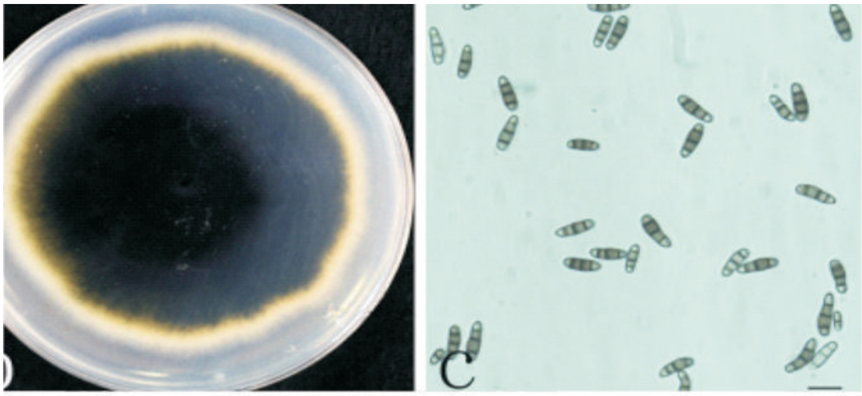

Fig. 6a 6b

Plate 6: a & b. Macro and micrograph of *Curvularia* sp. on CPA 10 days after incubation under room temperature at 20 ^{0}C and (b) = conidia (Scale bars = 20 μm).

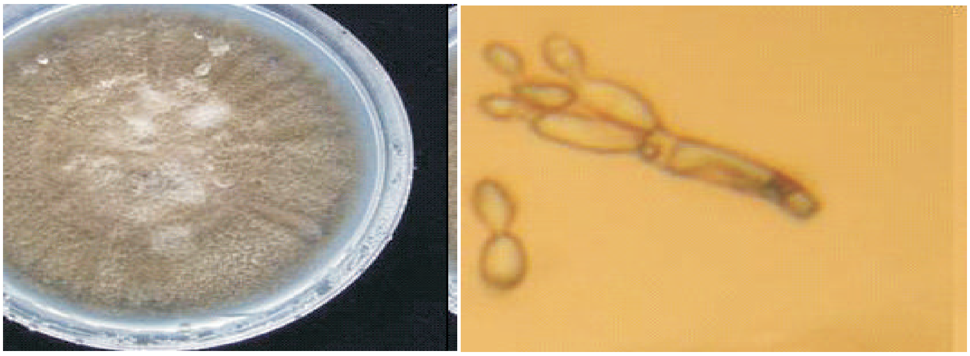

Plate 7 (a): Culture plate of *Cladosporium spp.* (b) Micrograph of *Cladosporium spp.* (scale bars = 10 μm). **Plate 7 (a & b):** Colony characters (a, b), and conidia (C) of *Cladosporium spp.* cultured on Carrot potato agar (CPA) at room temperature for 8 days in the dark

DISCUSSION

The results of this study showed that incidences of Cocoyam leaf blight (CLB) were high in all the locations/farmers visited. Similar findings were reported by several scientists within the country and other African countries (11;3). These high incidences from the study locations may be as a result of climate change, environmental factors or weather or farming practices (22;43;7).

Disease incidence increased across the communities under the survey. Barkin Ladi LGA of Plateau State had the highest disease incidence above 90% when compared with the other LGAs in Benue and Nasarawa States which indicated high level of infection/prevalence of the diseases in the study areas. Meanwhile, Akwanga and Kiyana LGA and Logo LGA of Nasarawa and Benue States recorded the lowest disease incidences of 80.15% and 83.68% and 82.19% and 81.16% in 2019 and 2021 respectively. Even though these incidences were not significantly different ($p \leq 0.05$), it's an indicative of a great risk of the crop loss by farmers in the areas under study (29;33b).

Similar finding were obtained by Zarafi *et al.* (49) and Ume *et al*., (44) who reported high disease incidences of about 80-100% in a survey of farmers' cocoyam fields for incidence of leaf blight conducted in Samaru Zone and few locations in Lere Zone of Kaduna Agricultural Development Project (KADP), Kaduna State and South-Eastern Nigeria respectively.

However, there was no significant difference (p>0.05) in disease incidence among the States and LGAs in 2019 and 2021. Thus, this study does not agree with the report by Adinde *et al*. (2016) who stated a significant difference ($p<0.05$) in TLB disease incidence among the villages in their study in Iwollo, South-Eastern Nigeria.

However, the study agreed with Onyeka (33), who reported TLB incidence range of 65% to 90% within fields where he evaluated 70 farmer's field across 8 states representatives of cocoyam growing agro-ecologies of Nigeria. Omane *et al.* (28), Chiejina and Ugwuja (11), Van der Puije *et al*. (45) and Abdulai *et al.* (1) all reported a similar findings and attributed significant difference in incidence of *Phytophthora* leaf-blight of cocoyam in some farms within Ghana, Nsukka area and Aowin Suaman districts of Ghana to differences in agronomic practices observed by individual farmer before, during and after planting respectively.

Bandyopadhyay *et al.* (9) and Omane *et al.* (28) reported that *P. colocasiae* is disseminated by means of vegetative propagation materials due to few accredited supply centres for cocoyam planting materials in the country that are not at the reach of local farmers both in terms of cost and distance. Farmers rely on families, neighbours and open markets for their supplies of propagation materials, which most times, already infected from the fields. The importance of weather conditions such as rainfall, temperature, humidity, etc. in the spread of this disease in the study areas cannot be overemphasized. Again, the temperatures changes between 18-27 ^{0}C and topography witnessed in some parts of Plateau State were the optimum conditions for the pathogen's growth and sporulation Tsopmbeng *et al*. (41) reported that temperature influences pathogen development. These changes in the factors might have stimulated the release of infective zoospores, promoting multiple infections in this study, thus, the high incidence in this location.

This agreed with the report by Lakshmi *et al*. (22), Ume *et al*. (44) and Aminu and David (7) who in their separate studies reported on the impact of weather parameters and functional relationship of environmental factors affecting cocoyam production and the prediction of *Phytophthora* leaf blight incidences and severities of cocoyam (*C. esculenta*) under natural epiphytotic.

The isolation of other five (5) fungi (*Cladosporium spp., Curvularia* sp., *Pythium* spp., *Fusarium oxysporum* and *Aspergillus niger) from the leaves and petioles of the diseased cocoyam samples from farmers' fields alongside Phytophthora spp. prompted the further confirmation by CABI in March 2024 through* molecular assays even though not discussed or reported under this review.

The percentage frequency of occurrence of each fungal isolates in all surveyed farms showed that *Phytophthora spp.* was the highest *(22%) followed by Fusarium oxysporum* and *Curvularia* spp. both with (15%) while *Alternaria alternata* had the lowest (10%). This study differed from the result presented by Shut *et al*. (39) where they reported a lower percentage occurrence of these fungal isolates in all surveyed farms in Jos East LGA of Plateau state where *A. niger* had the highest (17.4%) while *Alternaria* sp. had the lowest (4.3%). Meanwhile, the *presence of these fungi from the infested cocoyam fields may not be far fetch as contaminants or major pre or postharvest or soil fungi* believed to have emanated from planting materials or even as a result of cross contamination due to sample collection, rain splash from soil or cultural practices used during the propagation of the crop.

The cultural and morphological characteristics of these major fungi organisms isolated from the infected leaves and petioles were identical to those described by Watanabe *et al.* (46). Bensch *et al*. (10), Farr and Rossman (15), Jung *et al*. (20) and Shut *et al.* (39). This agreed with reports by other researchers (37; 49;8;6;16; 18; 3;32;31) on cocoyam leaf blight incidences with most of them having a very large and ubiquitous genus with several species.

CONCLUSION

From the current study it is evident that there was high disease incidence of cocoyam on farmers' fields across the twelve LGAs visited within the study locations. Thus, *cocoyam* production in North Central Nigeria can be perceived as problem in all the farms visited. This becomes the third report of *the incidence of cocoyam* on farmers' fields in some selected States in North Central Nigeria aside the one by Pandukur *et al*. (35) and Shut *et al*. (39).

Even though not reported under this review, three out of the six fungal isolates (*Phytophthora* spp., *Cladosporium spp.* and *Curvularia* spp.) were pathogenic. Their appearances of the disease symptoms differed as witnessed in the number of days it takes for lesion to occure. They all elicits different or complex symptoms with initial infections of water-soaked lesions that rapidly expand to form large brown spots at the leaf margins and patches of white to yellow or light brown with powdery zonate appearance pattern, and a conspicuous **black patches of circular or ring-like** brown spots on both lower and upper epidermis of the **older leaves** which later spread to the entire upper leaf surface 7-21 days after inoculation (DAI) in potted cocoyam seedlings in moist growth chamber and screen house. These three pathogenic fungi were later confirmed molecularly to be all *Phythophthora calocasiae* by CABI in March 2024. This implied that *Phythophthora calocasiae* is the main cause of CLB on the field. This agreed with the work by Adomako *et al*., (3) who reported that *Phytophthora* spp. was the cause of leaf blight on cocoyam in Ghana.

Keeping in view the importance of cocoyam and losses caused by cocoyam leaf blight pathogen, preventive disease control strategies should be adopted to combat and check the epidemic in the study areas, Nigeria and beyond since blight disease, when present, spreads at a faster rate. This can be made possible if specific characterization of the fungal isolates were done using molecular techniques that will ascertain if variability exists within the *Phytophthora* spp.

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