Incidence and severity of taro (*Colocasia esculenta* L.) blight disease caused by *Phytophthora colocasiae* in the Bono Region of Ghana

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Abstract

Taro leaf blight (TLB), a major disease of taro plant caused by Phytophthora colocasiae, a pseudo-fungus, and it occurs in many taro producing regions, especially in the southern part of Ghana. In the year 2019/2020, a survey was carried out in the Bono Region to determine the incidence and the severity of the disease in various taro fields. Infected samples were collected and the pathogen was isolated using potato dextrose agar (PDA). The pathogen was identified as P. colocasiae based on morphological characteristics. Naturally infected taro leaf and petiole samples were physically assessed and computed using the following formulae: Percentage incidence was equal to the number of infected plants over the total number of plants in a visited field/plot, multiplied by 100. The disease severity was calculated and scored on a 5-point scale as follows: Area of leaves infected over the total area of leaves, multiplied by 100. The results showed a wide-spread occurrence of the disease with varied degree of severities. Though, there was no significant difference in the disease incidence between Dormaa-Central (49.43 %) and Sunyani (54.21%) municipalities (P = 0.344), the disease was more severe in the latter municipality where the scores ranged from 1.383 – 1.705 than in the former municipality with a range of 0.756 – 1.674. Overall, the incidence and severity of the disease were significantly higher during the rainy period than in the dry period in both munic

Keywords - *Phytophthora colocasiae*, taro leaf bight, incidence, severity, wet and dry period.

I. INTRODUCTION

Taro [(*Colocasia esculenta* (L.) Schott], also known as old cocoyam, true cocoyam is a water-loving herbaceous plant, which simply represents crops in one of four genera in the family *Araceae*, namely *Cyrtosperma*, *Xanthosoma*, *Colocasia* and *Alocasia*.

Taro is ranked the 14th most consumed tuber vegetable in the world, with production capacity of 12 million tonnes generated from approximately 2 million hectares of land with a corresponding average yield of 6.5 tonnes/ ha [1]. The crop serves as staple food for more than 400 million people in the tropical and sub-tropical regions of the world [2] [3]. The root crop is mainly cultivated by small-scale growers in Latin America, Asia as well as Ghana in Africa [4]. In Sub-Saharan Africa, Ghana ranks third highest producer of Taro plants after Nigeria and Cameroon, and fourth in the world. In 2013 alone, Ghana produced approximately 1.2 million metric tonnes of corm yield [5]. The *Xanthosoma* spp. is locally known as 'mankani' or 'cocomankani' in Ghana and is the commonest member of the genus cultivated in Ghana. Taro is an economically important root crop that is cultivated predominantly in the Bono, Ashanti, Western and Eastern Regions that constitute transitional and forest zones of Ghana [6].

The plant helps in achieving food security because it is a multipurpose crop in which both the corms and leaves (popularly known as 'kontomire' in Ghana) are used in different forms as different food products [7] [8]. Taro plants have better nutritional qualities than other root crops like cassava, potato and yam and it is often cultivated by peasant farmers [9]. The plant is rich in minerals such as niacin, thiamine and riboflavin and some small amount of dietary fiber, as well as, some essential elements such as Calcium, Phosphorus, Magnesium and Potassium [9] [10] [11].The leaves are rich in fiber and are sources of other important nutritional compounds such as vitamins A and C. The leaves also have health benefits and are recommended for people with gastric problem, diabetic patients and the aged [12]. The tuber parts (corms and cormels) are eaten after frying, boiling or roasting. The tuber can also be used for making baking flours (bread and biscuits), pounded fufu, beverages, soups or sundried and milled into various semi-processed products [13]. The starch from the processed tuber which can be used as a substitute to an industrial starch [14], is easily digestible and suitable for making mashed appetizer weaning food called 'mpotompoto' for babies [15]. The starch can be used as a substitute for maize as a special binding material in the pharmaceutical industry in making drugs [16]. Cocoyam chips made from the corm are also common on Ghanaian streets where people buy and use them as snacks and desserts [13].

In the off-seasons of crops such as yam and plantain, taro tubers can be used as a substitute to these crops in preparing 'ampesi' or 'fufu'. In Ghana, women serve the major players in taro plant cultivation and trade and it serves as an alternative source of employment for the majority of them. As an important foreign trade commodity, the plant also contributes in a small way to Ghana's Gross Domestic Product [9]. Despite these numerous socioeconomic benefits of taro plants, the yield of this crop continues to decline yearly due to a number of constraints and among them is the problem of taro blight disease caused by a fungus-like Oomycete *Phytophthora colocasiae* Racib. The disease was first reported and described by Raciborski on taro plants in Java in 1900 [17], but there is some controversy about its center of origin [18] [19]. The pathogen is the most serious disease-causing organism that causes blight disease of Taro worldwide and is the principal cause of huge yield losses of up to 100% of both corm and leaf [20] [21]. The taro blight epidemics have the potential to reduce food availability with a corresponding increase in food prices, thus posing a serious threat to the rural dwellers and the regional food security. *Phytophthora colocasiae* is disseminated by the use of infected vegetative plant parts and possibly contaminated soil. This foliar pathogen has now assumed wide spread distribution with varied severity in Africa, East Asia, the Americas, the Caribbean and the Pacific and all the other taro growing areas of the world [22] [23]. The sporangia on the infected plant surface is easily disseminated via several means that include windy rains and splashing water from either irrigation or running water. Morphologically, although taro leaf surfaces are covered with trichrome, some small accumulation of water droplets can provide conducive environment for the pathogen spore germination. This pseudo- fungus can survive for a short while as a mycelium in the dead plant tissues as well as an infected corm and cormel. As a survival mechanism under dry stress conditions, the pathogen can thrive well in the soil as an encysted zoospore with thick cover layers or as chlamydospores which can survive in the soil in the absence of the host for several months [24] [25].

The most obvious symptoms of the disease are the blight of the leaf blade, other symptoms include postharvest rot of the corm, and rotting of the petiole in the susceptible varieties [26]. Early infection of the plant leaf is usually seen in places where there is enough accumulation of guttation droplets or dew or rainfall. The pathogen sporangia normally develop on the infected leaves and appear as small, brown, water-soaked necrotic areas, which rapidly coalesce into large lesions [27] from which yellow exudates appear, then follows defoliation and the death of the plant within some few weeks after infection [23]. The development of characteristic symptoms is dependent on the fluctuating day/night pattern. The cool night temperatures favour lesion expansion of about 3–5 mm wide water-soaked margins, which dry up during the day and back to water-soaked-status again during the night, resulting in zonation around the necrotic lesion which are easily seen when viewed from the bottom of the infected leaf [28].

Typical white powdery substances appear around the lesions during the night as a result of mass accumulation of sporangia. Another most common symptom of the blight disease on taro plant is the development, exudation and oozing of amber, reddish-brown or bright-orange droplets from both sides of the water-soaked margins, which dry out in the course of the day to form hard outer layer or covering on the surface of the necrotic tissue. Lesions with varying sizes can also be formed by the splashing or wind-blown sporangia. As the lesion expands, the central part of the infected tissue often breaks and falls. Infection of the petiole is only common in susceptible cultivars. The initial symptoms of the infection of the petiole are small, brown extended spots. Under wet, humid conditions, these spots can expand further, resulting in the tipping off or lodging of the plant due to the weight of the leaves [29]. The lesion expansion normally slows down during the dry season and the colour may change from tan to brown surrounded by dark brown margins. The center of the lesion of some resistant varieties normally becomes papery and disintegrate, leading to what we call "shot-hole" appearance [27]. Susceptible varieties of taro plant usually collapse within 20 days of infection as compared to those plants that are not infected, resulting in reduced photosynthesis because of reduced leaf size with corresponding decrease in corm size. This research was undertaken to assess the incidence and severity of taro blight disease in and around Sunyani and Dormaa-Central municipalities in the Bono Region of Ghana.

II. MATERIALS AND METHODS

A. Sample Collection & Isolation of Pathogen

A survey was conducted in and around Sunyani and Dormaa-Central municipalities during

2019 rainy period (July to end of the rains in November, 2019) and the dry period - 2019/2020 (November, 2019 to February, 2020) to assess the incidence and severity of taro blight disease in taro fields in these zones. Samples were taken during these two major periods/seasons to determine the incidence and the severity of the disease.

The experimental sites included the following communities: Odumase-Low cost; Gozokrom (2 zones, 3 blocks in each zone); and Penkwase (2 zones, 3 blocks in each zone) all under Sunyani municipality. Dormaa Ohenmaakrom (Agapet); KDS Abanpredease road; ABB down; Dormaa-Berekum road (near Puma gas); 3 zones in Nkyenkyenkye, namely: Nkyenkyenkye -Yeboah Kodie Street, Nkyenkyenkye-Eden words lane and Nkyenkyenkye (Yeboah Kodie Street II); SS- Akokonan Lane; Jericho- New Dormaa road; and Dormaa Jidiyeem all under Dormaa- Ahenkro municipality.

During the survey, some infected leaves and petioles samples showing noticeable symptoms such as the development, exudation and oozing of amber, reddish-brown or bright-orange droplets from both sides of the leaf margins, water-soaked necrotic areas, which coalesced into large lesions, white powdery appearance, blighted leaf blades etc. were randomly collected, packaged in the brown paper envelopes and sent to the University of Energy and Natural Resources laboratory for isolation and purification of the putative pathogen according to the fungus isolation protocols of [30] [31] with little modification. The isolation was done under a Laminar air flow chamber by cutting the diseased portion of taro leaves and petiole together with adjacent healthy tissue. The pieces were surface sterilized in 70% ethanol for 1 minute and thoroughly washed in three (3) exchanges of distilled water and blotted dry on Whatman paper for 2 minutes, after which they were plated on potato dextrose agar (PDA, Oxoid, England) at the 28°C for 7 days and examined on daily basis for the development of mycelial growth. The isolation was replicated three (3) times. The mixed population cultures were further purified through sub-culturing technique of transferring hyphal tip from the mycelium edge onto a new prepared PDA medium using flamed inoculation needle.

The pathogen was morphologically identified by preparing wet mount from the obtained pure cultures and with the aid of bi-nuclear microscope, the characters of the putative pathogen such as hyphae type, shape of sporangia, micro and macro conidia were morphologically examined and the features compared to standard established identification protocols by [32] [33] [34] [35] [36]

B. Disease Incidence

The occurrence of *P. colocasiae* on taro plant in the various fields was determined in this study. The sampling for disease incidence was carried out during the rainy period from July to the end of the rains in November 2019 and in the dry period - 2019/2020 (from November, 2019 to February, 2020) because the first rains of 2020 in the study areas started in March. In each locality, some of the fields were further divided into zones and sub-blocks. Disease incidence was assessed on the entire plants in each zone or sub-block. The percentage incidence of the blight disease was computed using the formula as the ratio of the number of taro plants with the disease symptoms to the total number of taro plants multiplied by 100 [37].

$$\text{Disease Incidence (\%)} = \frac{\text{Number of infected taro plants}}{\text{Total number of taro plants}} \times 100$$

C. Disease Severity Determination

The severity of the blight on the taro plant observed in the various locations across the municipalities in Bono region was calculated and scored as described by [37] below, and defined as the ratio of the area of taro leaves infected over total area of taro leaves multiplied by 100. 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.

$$\text{Disease Severity (\%)} = \frac{\text{Area of Taro Leaves Infected}}{\text{Total Area of Taro Leaves}} \times 100$$

Table (1): The 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

D. Weather Data

Data on the weather parameters in the study areas within the two municipalities in the Bono Region of Ghana were taken to determine the impact of weather on the incidence and severity of the disease. Bono Region is characterized by bimodal rainfall with peaks in July and September. The total amount of rainfall (mm), mean maximum and minimum temperatures (°C) and the relative humidity were recorded during the study period.

E. Data Analysis

The data collected on the disease incidence and severity were analyzed by analysis of Variance (ANOVA) using statistical software, GenStat release 12 Edition [38]. The mean variability among the incidence and severity of the disease on the taro plants per the locations were determined. The treatment means were separated using Tukey's Test and standard error was observed at 0.5% probability level.

III. RESULTS

A. Symptoms and Morphological Description of the pathogen

During the survey, samples showing conspicuous symptoms of the blight disease on taro were selected for a possible diagnostic purpose. Under normal growth conditions devoid of infection, taro plants look healthy and nonsymptomatic (Fig 1a), whereas infected plant harbouring the disease will display symptoms as shown in (Fig 1B).

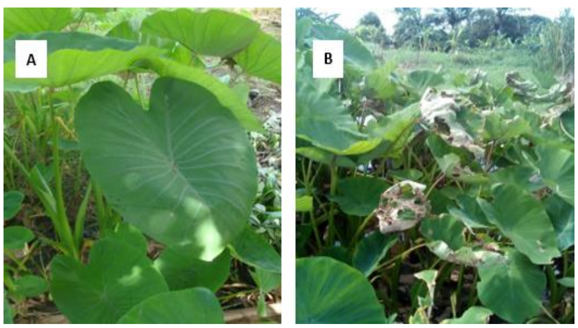

Fig 1: A. HEALTHY TARO PLANT B. DISEASED TARO PLANT

The first symptom observed in the infected taro plants, which gave an idea of the causal agent of taro blight disease based on the available literature in the various localities visited included: small, dark or light brown spots or flecks on the upper surface of the leaf (Fig. 2A). The spots often occur at the edge of the leaves where water normally accumulates (Fig. 2B).

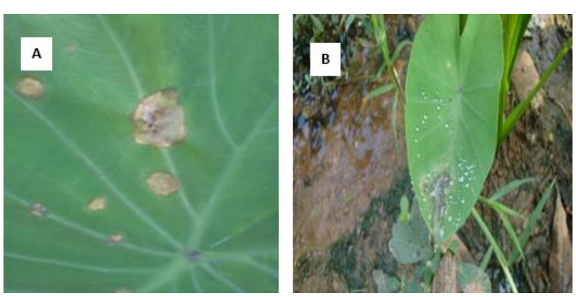

Fig 2: A. BROWN SPOTS or FLECKS ON LEAF SURFACE B. WATER ACCUMULATION SITES on LEAF SURFACE

The developed spots rapidly form large concentric zones on the leaves, which become brown in colour (Fig 3A) and in some situations with yellow halo surrounding the necrotic lesion (Fig 3B).

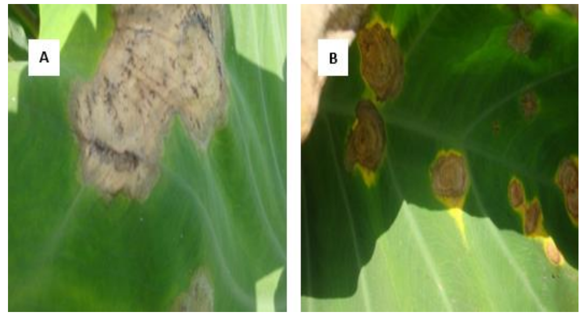

Fig 3: A. LARGE CONCENTRIC ZONES on TARO LEAF B. YELLOW HALLO SURROUNDING the LESION

The abaxial part of the leaf is also characterized by water-soaked appearance (Fig 4a) after infection. There is oozing of clear or light exudates around the water-soaked margins (Fig 4b), the exudate later changes to amber, bright-orange or brown droplets (Fig 5A- D), which dries out in the course of the day to form hard globules on the outer layer or surface of the necrotic tissues (Fig 5B,C,D). One of the conspicuous signs of the presence of the causal agent of taro blight disease is the whitish ring of sporangia that surrounds the margin of the lesion in the period of high relative humidity (Fig 5D).

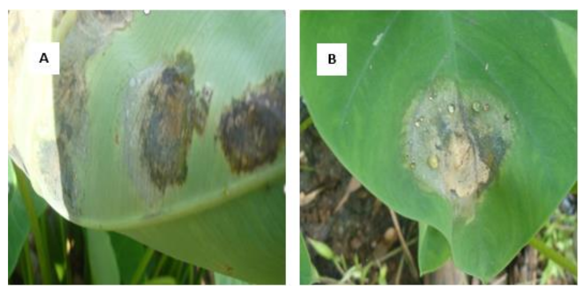

Fig 4: A. WATER-SOAKED APPEARANCE on TARO PLANT B. LIGHT EXUDATE from BOTH SIDES of The WATER-SOAKED MARGINS

Fig 5: A-D. FRESH and DRIED AMBER, BRIGHT-ORANGE or REDDISH-BROWN EXUDATE on TARO LEAVES

At the latter part of the plant development and at the peak of infection by *Phytophthora colocasiae*, the spots increased in size and coalesce, leading to the total blighting of the leaf and hence the name taro blight disease (Fig 6A, B).

Fig 6: TOTAL BLIGHTING of THE TARO LEAVES CAUSED by *P. COLOCASIAE*

In the resistant cultivars of taro plants, total blighting of the leaves is sometimes not common, instead, the central part of the infected tissues become papery, breaks and falls, creating what we call "shot-hole" appearance as shown in Fig 7 A, B.

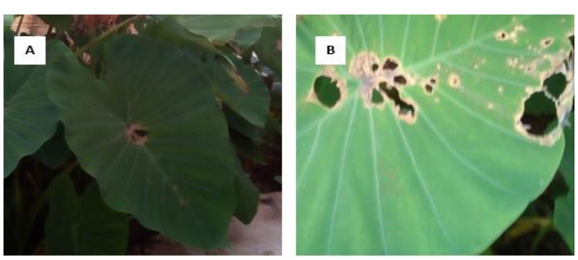

Fig 7: PAPERY "SHOT-HOLE" APPEARANCE on RESISTANT CULTIVARS of TARO PLANT

Taro leaf is not the only victim to the wrath of this pathogen, as the infection of the petiole is also commonly visible in susceptible cultivars. The initial symptoms of the petiole infection are small, brown extended spots. Under wet, humid conditions, these spots can expand further resulting in the tipping off or lodging of the plant due to the weight of the leaves. (Fig 8 A, B). This lodging of the taro plant as a result of infection of the petiole has also been reported by [29].

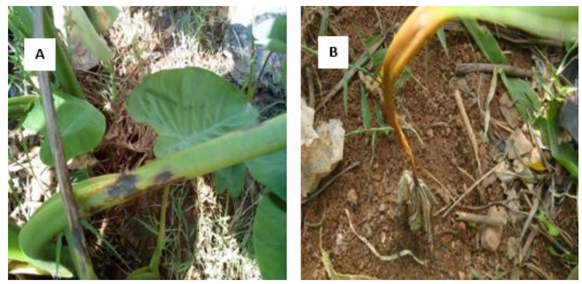

Fig 8: A. INITIAL INFECTION of THE PETIOLE with BROWN EXTENDED SPOTS B. LODGING of TARO PLANT

Taro plant tubers were also found to reduce due to infection and reduction of the leaves as a result of decreased photosynthesis and number of plants per stand. This was evident as a farmer at Gozokrom in the Sunyani municipality was displaying to us, reduction of tuber size of his infected taro field (Fig 9). Under normal conditions and without infection, healthy taro tubers should look like those provided in (Fig 10,A, B).

Fig 9: A FARMER DISPLAYING the REDUCED TARO TUBER SIZE DUE to INFECTION by *PHYTOPHTHORA COLOCASIAE*

Fig 10: A. HEALTHY, UNINFECTED TARO TUBERS B. CROSS SECTION of HEALTHY TARO TUBER

B. Morphological Identification

The putative pathogen extracted from the diseased taro samples across the municipalities in Bono Region was identified morphologically as *P. colocasiae* on the basis of sporangia, mycelia and other important characteristics such as colony, septation of the mycelium or hyphae and shape of sporangium using standard mycological identification key according to [39] [32] [33] [34] [35] [36]

The results showed the colony colour to be whitish or dull white on the media with fluffy and rosette characteristics in its growth (Fig 11). The hyphae were hyaline and coenocytic (aseptate) in nature. The sporangia were hyaline, ellipsoid to ovoid or globose, and semipapillate (Fig 12A). In the resting state, the pathogen has a thick-walled globose chlamydospores (Fig 12B). The characteristic features of the putative pathogen identified in this study were similar to the description explained by the above protocols, and thereby morphologically confirming the identity of the pathogen as responsible for causing blight disease of taro in the Bono Region of Ghana.

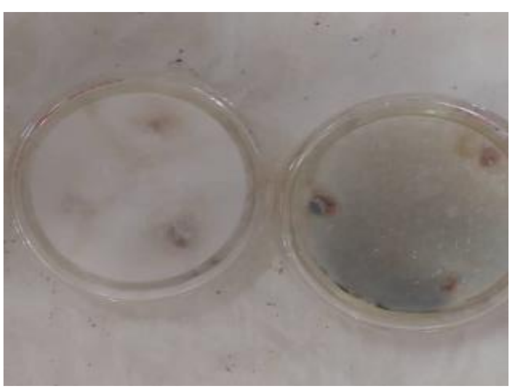

Fig 11: CULTURAL CHARACTERISTICS of *PHYTOPHTHORA COLOCASIAE* ISOLATED from CASHEW SHOWING WHITISH or DULL COLONIES

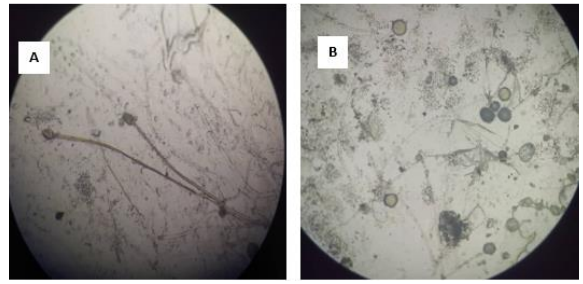

Fig 12: A. ASEPTATE HYPHAE WITH PAPILLATE SPORANGIA B. YOUNG GLOBOSE CHLAMYDOSPORES (40X)

C. Incidence & Severity of P. colocasiae

The survey showed that the taro blight disease was prevalent in and around Sunyani and Dormaa-Central municipalities. The results showed varied incidence and severity of the disease in the visited localities.

Disease Incidence:

The disease incidence averaged 49.43 % and 54.21% in Dormaa-Central and Sunyani municipality respectively (Fig 13) and did not differ significantly (P = 0.344). Overall, it was significantly higher (P = 0.002) for 2019 (rainy period) than 2019/2020 (dry period) (Fig 14).

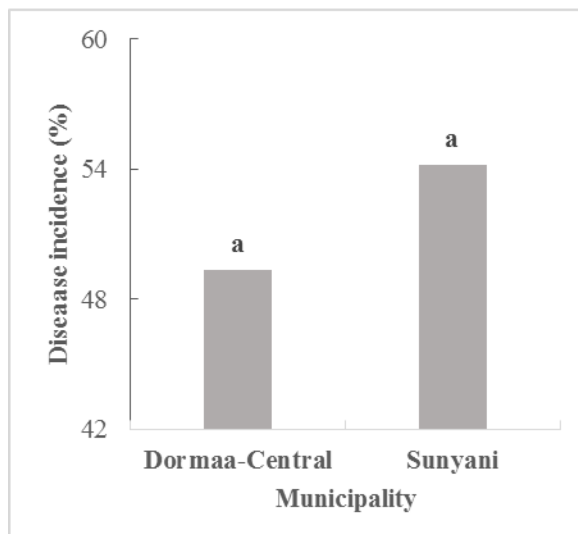

Fig 13: INCIDENCE of TARO LEAF BLIGHT in DORMAA-CENTRAL and SUNYANI MUNICIPALITIES in the BONO REGION of GHANA.

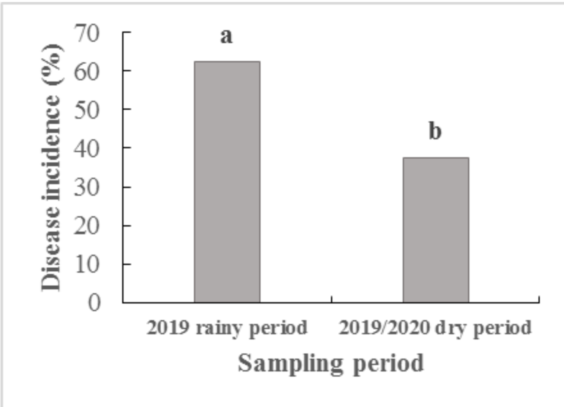

Fig 14: Incidence of taro leaf blight in 2019 rainy and 2019/2020 dry periods in Dormaa-Central and Sunyani Municipalities of the Bono Region of Ghana

Disease Severity:

Generally, the disease severity was affected by municipality ($P < 0.001$), by sampling site ($P < 0.001$), and by period of sampling ($P < 0.001$). The disease was more severe in the Sunyani municipality where the scores ranged from 1.383 – 1.705 than in the Dormaa-Central municipality with a range of 0.756 – 1.674 (Table 2). Within the municipalities, the least severity index was scored by ABB down, which was significantly different from all the other locations within Dormaa-Central municipality. Penkwase - Sunyani No. 1 and 2 recorded the least mean severity in the Sunyani municipality, but they were significantly different ($P = 0.002$) from only Gozokrom- Sunyani Zone 2 (Table 2). There were variations in the sampling period as well. It is seen from the figure that; rainy period recorded the highest severity score than the dry period (Fig.15).

Table (2): SEVERITY of TARO LEAF BLIGHT RECORDED for SAMPLING LOCATIONS WITHIN DORMAA-CENTRAL and SUNYANI MUNICIPALITIES in the BONO REGION of GHANA

Municipality	Sampling Site	Severity Score
Dormaa	ABB down Abanpredease road	0.756a
	Dormaa Ohenmaakrom (Agapet)	1.104b
	Jerico	1.313bc
	SS-AkokonanLane	1.348bc
	Nkyenkyenkye 2	1.361bc
	Nkyenkyenkye 3	1.403cd
	Jidiyeemu	1.446cd
	KDS Abanpredase road	1.464cd
	Nkyenkyenkye 1	1.507cd
	Dormaa-Berekum road	1.674 d
	P-value	< 0.001
	S.E.D.	0.065
Sunyani	Penkwase - Sunyani No. 1	1.383a
	Penkwase - Sunyani No. 2	1.457a
	Gozokrom- Sunyani Zone 1	1.468ab
	Odumase-Lowcost	1.615ab
	Gozokrom- Sunyani Zone 2	1.705b
	P-value	0.002
	S.E.D.	0.089

Mean values within same alphabets within each municipality are not significantly different from each other

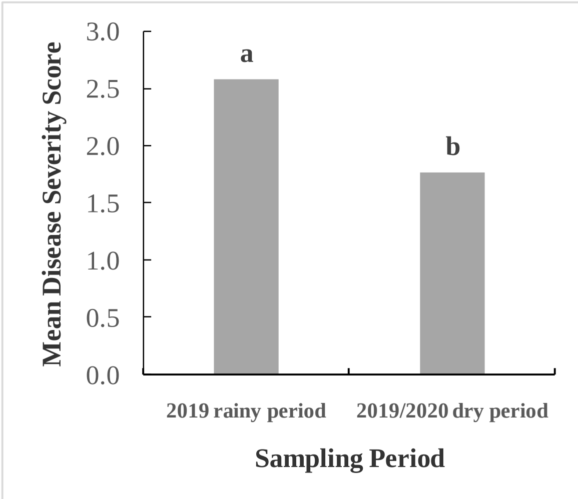

Fig 15. TARO BLIGHT DISEASE SEVERITY COMPARED in 2019 RAINY and 2019/2020 DRY SAMPLING PERIODS in DORMAA-CENTRAL and SUNYANI MUNICIPALITIES

D. Weather data

Figure 16 shows weather conditions such as total monthly rainfall (mm) and mean temperature (ºC) of the two municipalities. Both locations were of similar air temperature and rainfall pattern, but differed in the total amount of rainfall recorded during the period of sampling; the amount of rainfall was greater in the Sunyani municipality (1187 mm) than in the Dormaa-Central municipality (848.3 mm). The Agro-Meteorological data were sourced from the School of Agriculture (UENR)-Dormaa-Ahenkro campus and the Automatic Weather Station on the UENR Campus, Sunyani.

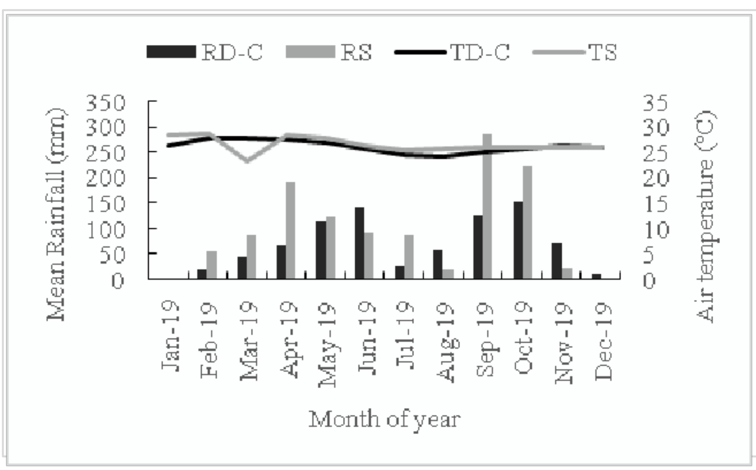

Fig16. WEATHER DATA SHOWING MONTHLY RAINFALL (MM) and AIR TEMPERATURE (^{O}C) RECORDED DURING ASSESSMENT of TARO LEAF BLIGHT DISEASE in DORMAA-CENTRAL (DC) and SUNYANI (S) MUNICIPALITIES of the BONO REGION of GHANA

IV. DISCUSSION

The incidence and severity of taro blight disease in relation to time of the two major periods of the years 2019 to 2020 were determined in this study using the score as described by [37]. Globally, it is generally believed that, diseases decrease agricultural productivity by more than 10%, which is comparable to half a billion tonnes of total food produced each year [40]. The impact of fungal diseases on crop production has been well explained by [41] who reported that, when fungal diseases are properly controlled on five (5) major crops alone, more than 600 million people could be fed each year in the world.

Taro plant is not an exception, as it is known to be infected by more than ten serious pests and diseases caused by a number of insect pests and pathogens across the globe [42]. Among all the disease-causing agents in taro plants, *P. colocasiae*, which causes leaf blight of taro is known to be the most important. This pathogen has been reported widely for causing leaf yield loss of 95% and 50% in postharvest rot of corm yield and quality [43] [44] [27] [45] [26]

It is believed that *P. colocasiae* is disseminated by means of vegetative propagation materials [22] [23], and the case may not be different for Ghana. There are no accredited supply centers for planting materials in the country, and farmers rely on families, neighbours and open market for their supplies of propagation materials, which may be coming from already infested fields. Hence, continuous chains of infections in the visited fields in the municipalities under consideration were very likely.

The constraints of taro blight disease to productivity of taro have been acknowledged in the West-African Sub-Region [22] [23] [46]. The disease poses serious threats to global food security as well as economic hardship to the people in these taro producing regions of the world. In Ghana, apart from the three northern regions, taro production is mainly carried out in the southern part of the country, and in order for farmers in this part of the country to increase taro productivity, there is a need for more research to determine factors likely to limit the productivity of taro. A few researches have been reported so far [47] [48] [49] [50]. Even then, the focus had been on the profitability of the taro enterprise. More studies such as ours reporting on the incidence of *P. colocasiae* are needed to provided valuable data to inform interventions towards the management of taro blight in the country.

The infected plants in the two municipalities exhibited a varied number of symptoms that included spots that developed on the taro leaves, and rapidly coalesced to form blight disease together with associated water-soaked, grey appearance or white powdery sporangia on the expanding ends of the necrotic lesions, yellow halo surrounding the necrotic lesion, amber or bright orange exudates oozing from the infected parts. All these symptoms have been tied to similar symptoms observed on the taro plant by [29] [27] [51] [52] and [53] in their respective studies. Also, on the very few suspected resistant taro cultivars, we observed that, total blighting of the leaves was not common and instead, the plant develops what is called "shot-hole" appearance, which were similar to findings as reported by [54] and [27].

Nelson et al., 2011 [27] reported that, earlier taro leaf infection by the pathogen usually takes place on the portion of the leaf where guttation droplets, water from the rains, irrigation or dew accumulates. Similar observation has also been made in the pictorial presentation of the results. During the survey, we found that, the petioles of some of the susceptible taro plants in the various fields visited were infected, the symptoms on the infected petioles were small brown spots, which later enlarges into bigger spots leading to the lodging of the plant due to the weight of the leaves. This assertion was corroborated by [26] [29].

To be able to control or manage taro blight disease, which usually limits the productivity of this crop, it is important that the pathogen is isolated from the diseased tissues and identified. On that basis, the pathogen was successfully isolated and identified morphologically as *P. colocasiae* based on the important characters of the pathogen using standard Mycological identification keys according to [32] [33] [34] [35] [36]. The sporangia are ovoid to ellipsoid with a well-defined narrow semi-papillate structure and are usually formed at the end of unbranched or casually branched sporangiophores at the edge of necrotic lesions. The sporangium is normally segregated from sporangiophores by the rain, leaving a small pedicel that is attached to their base [53], signifying the important role rain plays in the pathogen dispersal.

The incidence and severity of the disease are closely linked to the ability of the pathogen to be dispersed from one place to the other and hence the reason for the varied incidence and severity of the disease across the various fields in the municipalities.

The results of this study have provided evidence to the incidence of taro leaf blight in the Dormaa-Central and Sunyani municipalities, and add to the data of [23] who first reported incidence of the disease in the Eastern Region of Ghana. The seasonal changes have impacted incidence and severity of the pathogen on taro plant. Sunyani municipality registered the highest disease incidence and severity, and this could be attributed to the fact that, there has been more rains in this zone than as in the Dormaa-Central municipality. Dormaa-Central municipality recorded the least disease incidence and severity based on the score sheet. Also, our data will suggest a spread of the disease in the country. This then supports the call for disease surveys by [23] if effective monitoring were to be undertaken. The disease incidence of 49.43 % and 54.21% in Dormaa-Central and Sunyani municipality, respectively call for interventions to manage the disease since the weather conditions in the municipalities are about optimum for the development of the disease.

Also, considering the evolution of the disease incidence and severity in the various years or sampling periods, 2019 (rainy period part of that year- from July to November) and 2019/2020 (dry period 2019 to 2020- from November, 2019 to February, 2020), it was observed that, the rate of infection and the severity was higher during the rainy/early period than the late/ dry period in both municipalities. The rate of infection and symptom development on taro plant has been reported to decrease during the dry period as compared to the wet season [29]. Backing our assertion that, the incidence and severity were higher in the rainy period than the dry period was [55], who reported the spread of the disease via zoospores and sporangia throughout the field during rainy season with the onset of monsoon. Again,

the findings of this study are in agreement with those of [56] and [53] who observed high incidence and severity of the disease on taro plants at the onset of the rainy season, which disappeared when the dry season set off and vice versa. This pathogen that limits taro production in many regions of the world has been reported to relatively be short-lived on the infected plant parts and that, this could be attributed to its poor competitive saprophytic ability. It was found that as the dry period began to set in, and the amount of humidity also decreased due to seasonal limitation of water, a large number of infected leaves were hardly standing out. The only clue that will give an idea that there is an infection in the field, is the presence of dry infected leaf litter on the floor together with some countable and spatial number of spotted leaves.

The prevalence of the disease and the severity in all the localities surveyed within the region, could be due to the widespread cultivation of a single susceptible cultivar of taro plant throughout the region. Taro farmers in this region do not have a satisfied or accredited taro planting materials centres where they can source their suckers for planting, they therefore rely on local supply from the family, neighbours or markets where the purity of the planting material cannot be guaranteed and hence a continued trend of infections across the fields. Another factor that may likely trigger this high incidence and severity could be tied to an increase in relative humidity, coupled with low temperature, which is paramount for the establishment of the pathogen and onset of the disease resulting in an increased blighted taro leaf infection during rainy period than in the dry period. Taro leaf blight was found to be prevalent in almost all the taro producing provinces of India and serve as the major limiting factor for taro production in these areas, which cause yearly yield losses of 10 to 55% [55] [57], and in agreement with findings of this study, It was found the disease was prevalent in all the fields visited with varied infection intensities in the municipalities.

In a related work, Charles *et al*., 2016 [58], reported an increase in the incidence and severity of taro blight disease as the plant ages. They also recorded high incidence (100%) of the disease at 154 days after planting on all the taro cultivars investigated. They attributed this increased infection trend to the environmental conditions such as suitable temperature and high relative humidity, which could favour the disease establishment on the older plant than the younger ones. In this study, a similar trend has also been observed during the survey, where younger plants recorded lower incidence and severity of the disease as compared to the older ones. Though we agreed with the explanation of [58], this trend could further be attributed to differences in the physiological state of their growth as well as longer exposure (time) of the older plants to the previous season inoculum. For a disease to occur per the disease triangle rule, time is a critical factor determinant. in explaining this trend.

In some of the visited fields, farmers were found to intercrop *Colocasia esculenta* (taro plant) with *Xanthosoma sagittifolia* (elephant ear). Though these two plants belong to the same family (Araceae), it was observed that, the disease usually occurred only in the taro plant and not the latter, this could be attributed to the suggested resistance of *X. sagittifolia* to this pathogen that causes blight disease in taro plants. This result is in accordance with the findings of [28], who reported that, *X. saggittifolia* is immune to this disease.

The importance of weather conditions such as rainfall, temperature, humidity, etc. in the spread of this disease in the study areas cannot be overemphasized. Taro leaf blight has been reported to occur mostly in the early part of July to August and also, when the daily and night temperatures ranges between 25 – 28ºC and 20 – 22 ºC, respectively [52]. The effect of temperature on the incidence and severity of *P. colocasiae* causing blight disease on taro plant has been reported by [53]. These researchers submitted that, at wormer temperatures of 28 – 30°C, the sporangia of this pathogen germinate directly by the means of infection germ tube that can result in rapid and complete defoliation of the leaves as well as destruction of the entire taro plant. Brooks (2005) [29] reported *P. colocasiae* as weather pathogen that grows best in the temperature range of 27 – 30°C. The minimum and the maximum temperatures of this pathogen are 10°C and 35°C, respectively. Also related to the climatic conditions favouring the pathogen development, [29] again reported that, alternating day (warm humid) and night (wet) conditions, typical of tropical weather, favours the growth and spread of the disease on the taro plants.

There are several measures by which this pathogen causing taro leaf blight can be controlled or managed. These include management practices such as hygienic practices, use of disease-free planting materials, wide spacing between plants when planting, clearing, removal and burning of infected debris (leaves) during the initial stage of disease development, separating the diseased plant from the healthy ones, planting near forest plantations which can serve as a barrier to disease transmission to the taro plants [59] [60] [27]. Appropriate timing of planting is also recommended. For instance, [61] in his study was able to avoid serious taro blight disease in his field by planting during the dry season. Biological control such as the use of microorganisms, such as *Pseudomonas fluorescens*, *Trichoderma viride* have also been applied in the control of *P. colocasiae* [62]. Chemical control involving the use of systemic and protectant fungicides such as phosphorus acid (e.g. Foschek); copper (e.g. copper oxychloride); Mancozeb (e.g. Dithane M45) and metalaxyl (e.g. Ridomil Gold MZ) has successfully been used to control taro blight disease [59] [43] [27]. Lastly, the use of the most effective and promising management strategy is the utilization of resistant taro cultivars [57].

IV. CONCLUSION

All in all, this current study provides an important baseline information for the specific locations of the municipalities in the Bono region where taro blight disease is a serious threat and can warrant formulation and implementation of management strategies for taro protection in the study area and Ghana at large.

RECOMMENDATION

It is recommended that further researches should be undertaken in other taro-producing regions in Ghana to determine the levels of infection of taro blight disease. Future studies should also include the effect of taro blight disease on productivity of taro and income levels of farmers.

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