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Incidence, Severity, and Economic Cost of Ganoderma Butt Rot of Oil Palm in Ghana

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Abstract Ganoderma Butt Rot, an economic disease of the oil palm in south-east Asia and an emerging epidemic in Africa (West, East, and Central Africa), was uncovered in the Eastern Region of Ghana, in 2010. But knowledge gap, coupled with the absence of dedicated-GBR research, allowed the disease to spread steadily, killing infected palms, and endangering the oil palm industry in Ghana. GBR incidence, severity and spread in the Western, Central, and Eastern regions of Ghana, were surveyed quarterly for two consecutive years in selected-commercial oil palm plantations, and small-holder farms belonging to the staff of these commercial plantations. Using the systematic 'row-by-row walk-through' field survey method, single-point disease assessments were done using Standard Operating Procedure (SOP) with a severity scale of 0 – 4. Results show that the disease incidence for now, is low and endemic in the Eastern Region of Ghana. GBR incidence increased from a low of 6 palms to a high of 29 palms, over the period. Average monthly disease incidence was 1.21 palms and percentage annual disease incidence was 2.90% (or 0.86%/ha/yr). The annual epidemic rate (r) of GBR incidence in Ghana was 0.05 (r=0.05). The putative epidemic threshold was 5.80% (1.72%/ha/yr); epidemic cost was GHC 2 229.86 ($ 202.71) equivalent of fresh fruit bunch loss per hectare per year (FFB/Ha/Yr); and GHC 3 262.73 ($ 296.61) equivalent of crude palm oil loss per hectare per year (CPO/Ha/Yr). Ganoderma butt rot epidemic is predicted in the Western Region, due to the high incidence of coconut-oil palm succession, lack of awareness of the pathogenicity of Ganoderma, and farmer behaviour. This study has arguably provided the first quantitative data (percentage incidence, epidemic rate, economic threshold level, and epidemic cost) on the epidemiology of GBR of oil palm in Ghana, empirical bases for collective advocacy to prevent the disease from assuming epidemic or economic injury proportions in Ghana.

Keywords: *Ganoderma, Coconut-Oil Palm Succession, Knowledge-gap, Economic Cost, Ghana*

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1. Introduction

1.1. The Oil Palm

In Ghana, the oil palm is second to cocoa in the cash crop economy, contributing about 1 % of Ghana's GDP [1]. About 336 000 Ha under cultivation in Ghana [2], predominantly along the forest zones of the country where the climate is most suitable for oil palm cultivation [3]. Oil palm growth and yield are influenced by factors such as the quality of planting material, soil type and method of land preparation (zero-burning), crop spacing, weed, pest and disease management as well as crop nutrition [4].

Poor or unimproved planting materials often lead to poor yield resulting from high rate of adult sterility, floral abortion or bunch collapse. Poor soils such as waterlogged soils create conditions ideal for pests and diseases build up; water-stressed soils lead to stunting of growth, both of which result ultimately in low yields [4]. Narrow planting distance produces small fruit bunches, poor light incidence and humid conditions ideal for pests and disease build up especially fungal diseases. Wider than appropriate planting distance results in lower productivity of soils, regardless of their fertility or the quality of planting material. Weeds compete with oil palm for water, light, space, and nutrients. Poor weed control promotes pest and disease attack, delay fruiting and reduce yield. Pests and diseases cause economic loses if not properly managed [4].

All ages of oil palm (from seed nut; germinated seed; seedling; and field palm), are attacked by pathogenic organisms, especially, the fungi [5]. The most important fungal diseases of the oil palm in Ghana are the *Fusarium* wilt (*Fusarium oxysporum* f.sp. *eleadis*) and the *Ganoderma* butt rot (*Ganoderma* spp). The *Fusarium* wilt, is the most destructive, whereas *Ganoderma* butt rot is an emerging economic disease of the oil palm in Ghana (West, East, and Central Africa).

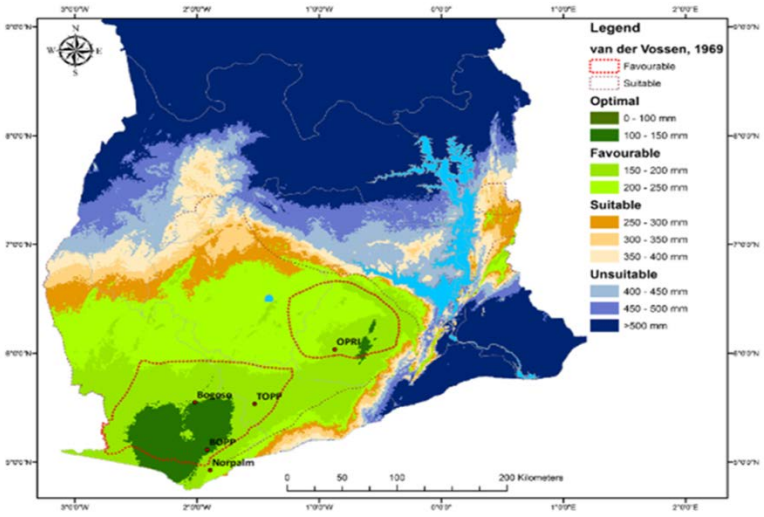


Figure 1. Map of southern Ghana showing areas climatically suitable for oil palm production [3]

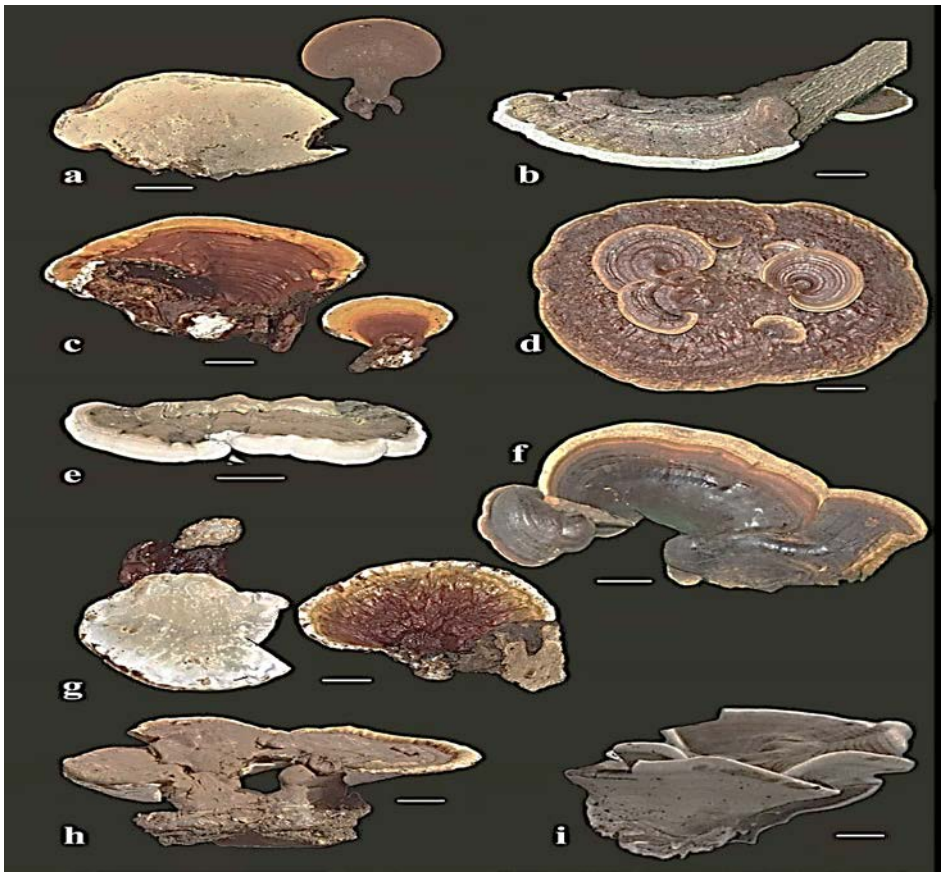


Figure 2. Mature Basidiocarps of some Ganoderma Species (bar = 2cm). **a.** Ganoderma orbiformum; **b.** G. perzonatum; **c.** G. praelongum; **d.** G. praelongum; **e.** G. philippi; **f.** G. resinaceum; **g.** G. sessiliforme; **h.** G.stipitatum; **i.** G. testaceum. Credited Source: [10]

1.2. The Coconut Palm

The coconut palm (*Cocos nucifera*, L) was presumably introduced to south-eastern Ghana (Keta, Volta Region) by the Portuguese Christian Missionaries over five centuries ago. In the year 1910, the British colonial government in Ghana promoted its large-scale cultivation along the coastal strip of the country (Volta, Central, and Western Regions). It is cultivated both as cash crop and food crop in Ghana [6].

Globally, the coconut palm is economically important as a source of fats and oils, and numerous industrial products. As far back as 1914, the coconut palm was the world's leading source of vegetable oil, in terms of volume of production and trade. In Ghana, an estimated 5.35 % of Ghana's population (estimated at 35 million in 2026), depend on coconut for their livelihood. Its cultivation, processing, and marketing offers employment to disadvantaged groups such as the landless poor, street children, and rural women [6].

1.3. The *Ganoderma* Fungus

The *Ganoderma* fungi are soil-borne basidiomycetes,

spread primarily through basidiospores [7,8]. Characteristically, they have a bracket-shaped fruiting-body in which gills are replaced by a solid structure (solid cone) with numerous pores [9]. Hence, they are also called the bracket fungi and polypore fungi, respectively (Figure 2) [10]. Locally, the *Ganoderma* is variously called *"hlo tri kpabaa"* (Ewe language: thick-flat mushroom), and *"mre boni"* (Twi language: bad mushroom).

They are solely terrestrial in habit, globally distributed (all green eco-systems; temperate and tropic), with over 300 species described [11].

They are principally plant pathogens, with a wide host range; over 44 species from 34genera of plants as potential hosts [12]. More than 144 plant hosts in India alone. As pathogens, they cause root rot and stem canker of plantation crops such as oil palm, coconut palm, betel palm (areca nut), rubber, tea, grapevines and other economically-important tropical crops [13]. But, as far as GBR is concerned, coconut and oil palm are the major hosts. In the natural forest, they attack preferably old and declining trees and decay dead wood and stumps.

The saprophytic species cause white rot of hard woods such as oak, conifers and maple [14,15].

The esculent species provide culinary delights such as beverages and delicacy (gano tea and reishi noodles) that are highly salubrious. Medicinal species produce biochemicals that are synthesized into steroids and antibiotics used in the treatment of gastric ulcer, chronic hepatitis, hypertension, nephritis, asthma, arthritis, bronchitis, insomnia, cancer, diabetes and anorexia [16].

1.4. *Ganoderma* Butt Rot (GBR) of Oil Palm in Ghana

Ganoderma Butt Rot (GBR), is a major economic disease of the oil palm in south east Asia and Africa. Caused by the soil-borne basidiomycete fungus, *Ganoderma* species, the disease shortens the productive life of the oil palm, leading to considerable economic losses to the oil palm industry in Africa and South-East Asia [13,17].

Affecting all stages of the palm, GBR is a silent-killer [18]; disease initiation, development, and expression take several years. The general symptoms are chlorosis, necrosis, and decay (Figure 3). The disease in the end, is a wilt; only the emergence of fruiting bodies on the stem of diseased palm as a final expression of disease [19], overrules *Fusarium* wilt of oil palm [20].

GBR is mostly found in tropical countries such as India and Sri-Lanka (south Asia), Guam and Papua New Guinea (Oceania), Indonesia, Malaysia, and southern Thailand (south-east Asia), Ghana, Cameroon, Tanzania, and Seychelles (Africa), and West Indies.

1.5. Economic Cost of Ganoderma Butt Rot of Oil Palm

GBR of oil palm has significant economic cost in Asia and Africa as illustrated below:

In Malaysia:

At 50 % incidence, there is approximately, 50 % loss in fresh fruit bunch (FFB) yield/ha/yr [21]. An equivalent of palm oil loss of USD 500 million per year **[11]**.

In Indonesia

Reportedly, up to 80% mortality and yield loss per unit area [22]. At 1% GBR incidence, an estimated USD 38 million is lost annually to oil palm companies in Indonesia [23].

In Cameroon

A 53.2% mortality reported in a first-generation planting [24].

In Ghana: Economic Cost of GBR is under documentation [20].



Frond Necrosis & Skirting Emergence of Sporocarps Tissue Decay & Trunk Collapse

Figure 3. Symptomatic phases of Ganoderma Butt Rot of Oil Palm in Ghana

1.6. Control of Ganoderma Butt Rot of Oil Palm

Control of *Ganoderma* fungus is difficult, because the fungus has several resting structures such as melanised mycelium, basidiospores and pseudo-sclerotia. However, cultural, mechanical, chemical and biological control methods have been applied in the management of GBR.

The most effective control method is the chemical control. This involves manipulation of soil nutrient levels (both macro-and micro-nutrients) and application of systemic fungicides. Examples include:

Fungicides: spraying with systemic fungicides such as triadimenol, root-feeding and soil drenching with tridemorph, and hexaconazole [25]

Agro-chemical fertilizers**:** high levels of Urea, Single Super-Phosphate (SSP), and Muriate of Potash (M.O.P) [26].

Macro-nutrients: prudent nutrient supplementation or soil amendment with Nitrogen (N), Di-phosphorus Pentoxide (P_2O_5), and Potassium Oxide (K_2O), etc [26]

Micro-nutrients: judicious application of Borax, Zinc Sulfate (Zn So_4), Gypsum [25].

2. Background

2.1. Plant Epidemic and Epidemiology

A plant disease once initiated, may develop and become established either as a localised infection (endemic disease) or a wide-spread infection (epidemic disease) [27]. An epidemic disease is one that affects several plants in the host population, over a relatively wide area, and in a relatively short time **[27]**. The critical measure of an epidemic is the rate of infection, ***r*** calculated from the slope of a disease progress curve. According to Plank's 1963 epidemic threshold theorem, iR > 1, an epidemic disease is one in which the average number of daughter foci (2^o) of infection per parent focus of infection always exceeds 1.

Mathematically, a disease in which the pathogen produces several reproductive cycles in the life of the host is governed by the Van der Plank's (1963) equation below:

X = xoert (1), where;

X = the number of diseased palms at any one time;

$\mathbf{X_o}$ = the initial number of diseased palms;

r = average rate of infection;

t = time during which infection occurred;

e = base of natural logarithm ($e= 1+ {}^1/n)^n$, where n is a very large number, =2.718…)

By log transformation and transposition, the Van der Plank's equation becomes:

R = 1/t loge (x/xo) (2).

Provided therefore, we have an initial amount of disease and a second amount some time afterwards we can calculate the average rate of increase over the period of time. By convention, the first measurement is $\mathbf{x_1}$ (assessed at time, $\mathbf{t_1}$) and the second $\mathbf{x_2}$ (assessed at time, $\mathbf{t_2}$). Average infection rate is given by:

r = 1/t2 - t1 loge (x2/x1) (3)

Epidemiological study provides the most comprehensive understanding of the elements of a crop disease. It gives insight on disease-initiating host-pathogen interaction factors; animate and inanimate environmental factors enhancing disease development; as well as human activities enhancing disease spread and associated crop losses. Such knowledge is useful for predictive modeling, forecasting, prevention and integrated disease management in a valuable crop.

2.2. Ganoderma Butt Rot (GBR) of Oil Palm

Ganoderma Butt Rot (GBR), a major economic disease of the oil palm in south-east Asia and an emerging epidemic in Ghana (Africa), was first uncovered in the Eastern Region of Ghana, in 2010 [20], but there was lack of indigenous knowledge on epidemiology, and control of the disease. The knowledge gap, coupled with the absence of GBR research, allowed the disease to spread steadily, killing infected palms, and endangering the oil palm industry in Ghana.

Disease measurement is the "cornerstone of epidemic analysis" [28]. "Without quantification of disease, no studies in epidemiology, no assessment of crop losses, and no plant surveys and their applications would be probable" [27]. Yet, such quantitative data on the epidemiology of GBR of oil palm in Ghana is hardly available.

The objective of this study therefore, is to quantify incidence, measure severity, spatio-temporal distribution, and economic cost of *Ganoderma* butt rot of oil palm in Ghana. The goal is to identify the factors complicit in *Ganoderma* butt rot of oil palm epidemiology, device mitigating strategies against GBR incidence and spread and finally develop an epidemic map of Ganoderma butt rot incidence, as the basis for *Ganoderma* butt rot epidemiological surveillance network in Ghana.

3. Materials and Methods

3.1. Climatic and Edaphic Characteristics of the Studied Regions of Ghana

The Western Region is located in the south-western corner of Ghana between latitude 5º N and 30º S and longitudes 3º E and 32º W (Figure 4). The regional landmass is approximately 239 221 square kilometers; representing 10% of Ghana's total land area. Arable land area is 17 641 km^2 (approximately, 73.8 % of total regional land area). Land area under cultivation is estimated at 6 720 km^2 (about 38.1 % of arable land). The major agricultural activities include: crop production (74 %), animal husbandry, and agro-processing.

The Central Region, is located in the south-western center of Ghana between latitude 5º 29' 59.99" N and longitudes -1º 00' 0.00" W (Figure 4). The regional landmass is approximately 9, 830 km^2, equivalent to 4.1 % of the total landmass of Ghana. Of this, 7 864 km^2 (representing 80 % of the total regional land area) is arable. However, only 3 932 km^2, representing 40 % is under cultivation presently. The Central region has the longest coastline in Ghana, measuring approximately 150 km^2.

The Eastern Region, is located in the south-eastern part of Ghana, between latitude 5º 30''N and 7º 22'' S and longitudes 0º 30" E and 1º 30" W (Figure 4). The regional landmass is approximately 19 320 km^2, representing 8.1 %

of the total landmass of Ghana. The topography of the region is generally undulating with large stretches of flat land in the Afram Plains, and highlands in the Kwahu scarp (77.8 m), Atiwa-Atweredu range (720 m), and Akwapim range (450 m).

The Western, Central, and Eastern Regions are contiguous; sharing common boundaries and having similar climatic and edaphic features. Like the Western and Central regions, the Eastern Region has a bi-modal rainfall pattern; the major season being March to July, and minor season being September to November (Figure 4). Altogether, the climatic and edaphic characteristics of the Western, Central and Eastern Regions of Ghana are summarized in Figure 4; Table 1.

Table 1. Climatic and edaphic characteristics of the Western, Central and Eastern Regions of Ghana

Parameter	Western	Central	Eastern
Mean Ann. Tempt (°C)	22°C - 34°C	24°C - 34°C	22°C - 33°C
Mean Ann. Rainfall (mm)	1 600mm	1200mm	1400mm
Relative Humidity (%)	5% - 90%	50% - 80%	65% - 95%
Predominant Vegetation	Forest (75%)	Forest (55%)	Forest (65%
Topography (major)	Highlands	Undulating/flat	Highlands/flat
Arable Land Size (km^2)	17 641(6 720)	7 864 (3 932)	-
Major Soil Type (s)	Sandy-loam/ Ochrosol	Fine sandy loam/ Ochrosol	Forest ochrosol/ Lithosol
Agro-ecological Zones	Forest, Coastal Coastal Savannah	Forest, Transitional, Coastal Savannah	Forest, Trans Coastal Savannah
Von der Vossen Climatic Index: (water deficit index for oil palm)	Optimal 0 – 150 mm	Optimal 0 – 150 mm	Favourable 150 – 250 mm



Source: Created with Open AI (2006); AI-generated Image -DALLE.

Figure 4. Map of the southern belt of Ghana showing the three contiguous oil palm regions (Western, Central, and Eastern) used for the GBR study in Ghana

3.2. Communities (townships) and District in the Three Regions for the GBR Epidemic Survey

Ewusie-joe, in the Ahanta West District of the Western Region, Twifo Ntafrewaso, in the Atti-Mokwa District of the Central Region, and Kusi, in the Denkyembour District of the Eastern Region, with commercial oil palm plantations Norwegian Palms Ghana Limited (NORPALM), Twifo Oil PLM Plantation (TOPP), and the Oil Palm Research Institute (OPRI) respectively, were selected for the GBR epidemic survey in Ghana.

Ewusie-joe, in the Ahanta West District of the Western Region was chosen because it is both a Cape Saint Paul Wilt of coconut focus, and a hub for commercial oil palm cultivation. Twifo Ntafrewaso, in the Atti-Mokwa District of the Central Region was chosen because, together with the Western Region, they are two of the tree major coconut cultivation regions in Ghana, where many disenchanted farmers are cutting down their CSPW-devastated coconut farmers to plant coconut or rubber. Kusi, in the Denkyembour District of the Eastern Region was chosen because, besides being the biggest oil palm hub in Ghana, it was the only region with active *Ganoderma* butt rot incidence in Ghana, at the inception of this research study (Table 2).

Table 2. Commercial Oil Palm Plantations Used in GBR Study in Ghana

Indicator	NORPALM	TOPP	OPRI
Region	Western	Central	Eastern
District	Ahanta West	Atti-Morkwa	Denkyembour
Location	Ewusie-joe	Twifo Ntafrewaso	Kusi
Established	2000	1977	1988
Total Land Area (Ha)	4 591.43	4 653	1 080
Cultivated Area (Ha)	4 031.44	4 293	580
Major Products	CPO/CKO	CPO/CKO	FFB/Seed

Footnote: Data valid as at December, 2022

3.3. GBR Epidemic Survey

By conventional wisdom, commercial crop plantations being more financially-resourced, and managed by more-educated and highly-skilled professionals, deploy best agricultural practices (or at the very least, good agricultural practices) unlike less-educated and unskilled

peasants or smallholder farmers. Farm lands are prepared correctly for planting, planting is done on time and at the correct planting distance, using certified and improved planting materials (high percentage germination, growth vigour, pests and disease-free, early-maturing and high-yielding propagules), strict phytosanitary, fertilizer, and moisture (mostly by irrigation) regimes are observed to the letter. The overall benefit of these best agricultural practices are less incidences of pests and diseases, sustained or enhanced soil fertility, and optimal yields.

Peasants or resource-poor small-scale crop farmers, on the other hand, are not capable of best or good agricultural practices. As a result, growth, pest, disease, and yield dynamics can be significantly different. Therefore, it is standard practice in agricultural science research, when conducting parametric studies (growth, yield, pest and disease incidence, drought resistance, etc) on large-scale or commercial crop plantations to include peasant or smallholder farms for an analogous study. This provides a sound basis for comparison, and a reasonably objective basis for reaching conclusions. Generalising observations or scientific facts from scientific studies conducted on well-curated commercial farms over peasant farms, is most inappropriate and misleading. All the studies were conducted on commercial oil palm plantations and proportionately-replicated on smallholder oil palm farms in Ghana.

The disease incidence, severity and spread in the Western, Central, and Eastern regions of Ghana, were surveyed quarterly for two consecutive years. The GBR epidemic forays were conducted on the selected commercial plantations as well as the small-holder farms belonging to the staff of these commercial estates (Figure 1; Table 2). Using the systematic 'row-by-row walk-through' field survey method, single-point disease assessments were done using Standard Operating Procedure (SOP) with a severity scale of 0 – 4.

GBR incidence was determined by visual observation based on the known symptoms of the disease (chlorotic leaves, multiple spears, frond die back, frond collapse, cessation of male flower development, collapsed crown, and presence of fruiting body at butt of palms, etc). In each plantation, disease incidence was assessed by counting the number of symptomatic palm trees in a block of 100 palms per hectare, along a diagonal plane to ensure uniform and accurate representation of disease incidence. Visual assessment of disease severity was based on modified disease severity scale (0 - 4), developed by Abdullah *et al.*, 2003 (modified-severity scale; Table 3).

In all cases, palms were at least 15 years old, but less than 25 years. In each region, large scale plantation (LCP) to small scale plantations (SCP) were chosen in a 4:1 ratio; 400 palms LCP: 100 palms SCP (approximately, 4 hectares LCP: 1 hectare SCP or 100 palms per hectare) respectively. Altogether, 15 hectares of oil palm farms, representing 1 500 palms were surveyed in all three regions (500 per region x 3 regions = 1 500 palms)

Table 3. Severity scale of *Ganoderma* Butt Rot of Oil Palm in Ghana

Severity Class	Description
0	Healthy looking palm with chlorophyllous leaves, but without fungal mycelium on any part of the palm
1 (Low)	Apparently unhealthy palm with chlorotic leaves and unopened spear leaves, but without white fungal mass on palm
2 (Moderate)	Conspicuously-diseased palm with chlorotic, necrotic, and skirting of leaves, and presence of basidiomata on any part of palm
3 (Severe)	Generalised chlorosis, necrosis, and presence of well-developed basidiocarp(s) on butt of infected palm (physiological death)
4 (Terminal)	Death of palm, bole tissue-disintegration, and trunk collapse

Credit: [Abdullah *et al*., 2003; as modified by Danyo *et al*., 2026]

3.3.1. Computation of the Incidence of Ganoderma Butt Rot of Oil Palm in Ghana

Disease count was computed using a modified formula by Abdullah *et al*., [29], as illustrated below:

$$\%\ GBR\ Incidence = \frac{\text{Number of symptomatic palms within the scale (1- 4) x 100 \%}}{\text{Total number of oil palms surveyed in a plantation}}$$

3.3.2. Determination of the Epidemic Rate (*r*) of Ganoderma Butt Rot of Oil Palm in Ghana

Average infection rate or epidemic rate (*r*) of GBR was calculated using a transformed Van der Plank's 1963 epidemic threshold theorem equation illustrated below:

$r = {}^{1}/_{t2\,-\,t1} \log_e (x_2/x_1)$ …….. (1), where:

X = the number of diseased palms at any one time;

X_o = the initial number of diseased palms;

r = average rate of infection;

t = time during which infection occurred;

e = base of natural logarithm ($e= 1+ {}^{1}/n)^n$, where n is a very large number, =2.718…)

3.3.3. Determination of Economic Cost (EC) of *Ganoderma* Butt Rot of Oil Palm in Ghana

Plant epidemic or epiphytotic causes economic injury, and therefore, has economic cost (ec). The economic cost (ec) of GBR in Ghana was calculated using average annual oil palm mortality (fresh fruit bunch yield loss) to GBR infection, the average annual producer prices per tonne of fresh fruit bunch (1tonne FFB = GHC 1 570.32) and crude palm oil (1tonne CPO = $ 8 000 or $8 per kg) by the regulator, Tree Crops Development Authority (TCDA, January, 2026 Producer Price Index; htpps://www.tcda.gov.gh) [30]

For statistical adequacy, reliability, and based on standard standing crop of 148 palms per hectare, extrapolated percentage annual GBR incidence per hectare data (extrapolated from percentage annual GBR incidence data in Lekete-Lawson *et al*., 2025); 0.56%/ha/yr, and the actual calculation from the present study (0.86%/ha/yr)

were pooled, and the total percentage annual incidence (1.42%/ha/yr) was used to determine the epidemic cost of GBR incidence in oil palm in Ghana.

At 100 % annual GBR incidence, fresh fruit bunch (FFB) yield loss per hectare per year = GHC 157 032.00 /ha/yr ($ 14 275.64 at: $1 = GHC 11 forex; 10 tonnes FFB/ha/yr yield; and 1tonne ffb price of GHC 1 570.32). At the current annual percentage GBR incidence of 1.42% per hectare, an equivalent of GHC 2 229.85 ($ 202.71) of FFB/ha/yr is lost in Ghana to GBR infection.

At the same rate, crude palm oil (CPO) loss per hectare per year = GHC 229 770.00 ($ 20 888.18). At the current percentage GBR incidence of 1.42% per hectare per year, an equivalent of GHC 3 262.73 ($ 296.61) of CPO/ha/yr is lost in Gnana to GBR infection.

Average yields of fresh fruit bunch per hectare per year (FFB/ha/yr) and crude palm oil (CPO) yield per hectare of FBB (CPO/FFB/Ha/Yr) are based on annual upper limit values for small-holder farmers, and lower limit values of commercial oil palm plantations;10 tonnes FFB/ha/yr yielding 1.2 tonnes CPO/ha/yr. This is the first-ever computation of economic cost of *Ganoderma* butt rot (GBR) of oil palm infection in Ghana.

4. Results and Discussions

An epidemiological study provides the most comprehensive understanding of the elements of a crop disease. It gives insight on disease-initiating host-pathogen interaction factors; animate and inanimate environmental factors enhancing disease development, as well as human activities aggravating disease spread and associated crop losses.

The Western, Central, and Eastern Regions are contiguous; sharing common boundaries and having similar climatic and edaphic features. Altogether, the climatic and edaphic characteristics of the Western, Central and Eastern Regions of Ghana are summarized in Figure 4; Table 1. Like the Western and Central regions, the Eastern Region has a bi-modal rainfall pattern; the major season being March to July, and minor season being September to November (Figure 4).

Results of the GBR epidemic studies are presented in Tables 4 - 6 and Figure 5. GBR incidence increased from a low of 6 palms to a high of 29 palms, over the period. Average monthly disease incidence was 1.21 palms and overall percentage annual disease incidence was 2.90% (or 0.86%/ha/yr) The overall annual epidemic rate (*r*) of GBR incidence in Ghana was 0.05 (*r = 0.05*). The epidemic cost was GHC 2 229.86 ($ 202.71) equivalent of fresh fruit bunch loss per hectare per year (FFB/Ha/Yr); and GHC 3 262.73 ($ 296.61) equivalent of crude palm oil loss per hectare per year (CPO/Ha/Yr) (Table 5).

At percentage cumulative annual GBR incidence of 5.80% (1.72%/ha/yr), the assumed economic threshold (ETL) for the integrated disease management (IDM) paradigm for GBR of oil palm in Ghana was attained. Therefore, the GBR active farm was completely felled to curtailed disease spread within farm, and to contiguous farms.

The 5.80% (1.72%/ha/yr) economic or action threshold in GBR management in Ghana is key, because the disease is a silent-killer [18]; disease initiation, development, and expression take several years. And though, the general symptoms are chlorosis, necrosis, and decay, the most conclusive diagnostic symptom is the emergence of fruiting bodies on the stem or butt of infected palm. But this occurs as a terminal or final expression of disease [19], leaving the farmer or the crop protectionist no chance to reverse or cure the disease [20].

Disease incidence was higher during the drier seasons of the year (between November and February) (Figure 5). Therefore, drought or water stress appears a significant factor in GBR symptom expression, that is GBR incidence and severity levels were more conspicuous in the drier months of the year.

Majority of the infected palms were aged (nearly 25 years old), confirming the knowledge that *Ganoderma* prefers old and declining host plants. The declining natural immunity and growth vigour of older palms render them easily overwhelmed by GBR.

Without quantification of disease, no studies in epidemiology, no assessment of crop losses, and no plant surveys and their applications would be probable" [27]. This study has arguably provided the first-ever quantitative epidemic data and empirical epidemic rate (*r = 0.05*); the putative economic threshold level (ETL) of 5.80% (1.72%/ha/yr), and the epidemic costs (EC) of GHC 2 229.86 ($ 202.71) FFB loss/ha/yr, and GHC 3 262.73 ($ 296.61) CPO loss /ha/yr of *Ganoderma* butt rot in Ghana (Table 5).

Table 4. Ganoderma Butt Rot of Oil Palm Quarterly Incidence and Severity Scale in Ghana

Time (Quarterly)	Palms Per Severity Level				Diseased Palms	Percentage Disease	Percentage Disease/Hectare/Year
	1	2	3	4			
Q1	0	0	2	4	6	1.20 %	0.35 %/ha/yr
Q2	3	1	0	0	4	0.81 %	0.24 %/ha/yr
Q3	3	0	0	0	3	0.61 %	0.18 %/ha/yr
Q4	1	1	0	0	2	0.41 %	0.12 %/ha/yr
Yearly Total	7	2	2	4	15	3.03 %	0.89 %/ha/yr
Q5	0	0	3	2	5	1.63 %	0.48 %
Q6	3	1	0	0	4	0.83 %	0,25 %
Q7	1	2	0	0	3	0.63 %	0.19 %
Q8	2	0	0	0	2	0.42 %	0.12 %
Yearly Total	4	5	3	2	14	3.51 %	1.04 %/ha/yr
Cumulative	11	7	5	6	29	6.54 %	1.93 %

Table 5. Significant Epidemic Indices of Ganoderma Butt Rot of Oil Plam in Ghana

GBR Epidemic Index	GBR Epidemic Value/Cost
Percntage Annual Incidence Per Hectare (% DI)	0.86 %/Ha/Yr
Annual Epidemic Rate Per Hectare (r)	0.05/Ha/Yr
Annual Economic Threshold Level Per Hectare (ETL)	1.72%
Annual Economic Cost (EC):	
Loss of FFB/Ha/Yr	GHC 2 229.86 ($ 202.71)
Loss of CPO/Ha/Yr	GHC 3 262.73 ($ 296.61)

Table 6. Ganoderma Butt Rot of Oil Palm Epidemic Cost at Benchmark Annual Percentage Incidences

Percentage Annual GBR Incidebce	Epidemic Cost (FFB/Ha/Yr)		Epidemic Cost (CPO/Ha/Yr)	
1	GHS 1 570.32	USD 142.76	GHS 2 297.70	USD 208.88
5	GHS 7 851.60	USD 713.78	GHS 11 466.50	USD 1 044.41
10	GHS 15 703.20	USD 1 427.56	GHS 22 977.00	USD 2 088.81
50	GHS 78 516.00	USD 7 137.81	GHS 114 885.00	USD 10 444.09
100	GHS 157 032.00	USD 14 276.00	GHS 229 770.00	USD 20 888.00

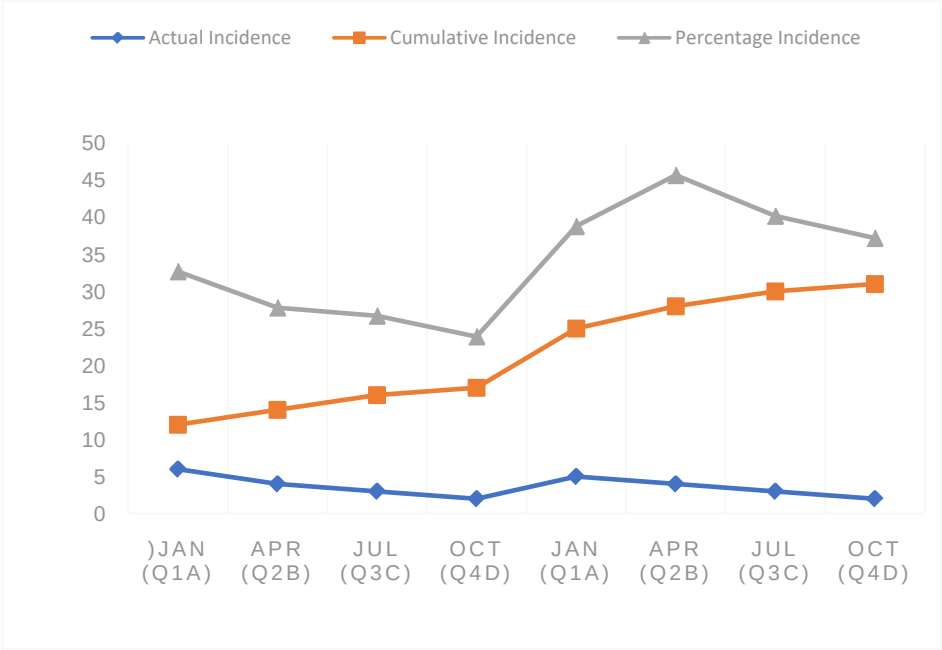


Figure 5. Ganoderma Butt Rot of Oil Palm Incidence in Ghana (Kusi-Eastern Region)

5. Conclusions and Recommendations

According to Plank's 1963 epidemic threshold theorem, iR > 1, an epidemic disease is one in which the average number of daughter foci (2o) of infection per parent focus of infection always exceeds 1. But no disease ever starts as an epidemic, rather epidemics develop over time.

An overall epidemic rate of 0.05 (r = 0.05), clearly shows that, the disease is building up into an epidemic in Ghana. This gives ample time and space to comprehensively study the disease, and formulate strategies for GBR prevention or effective containment in Ghana. This certainly will involve the development of peculiar integrated management of GBR in Ghana, in which case screening and assessment of both biotic and abiotic stressors will be an imperative.

This study arguably, provides the first-ever and most comprehensive quantitative data on the epidemiology of GBR of oil palm in Ghana. The trailblazing epidemiological studies creates adequate awareness of the GBR epidemic potential in Ghana. The empirically-established epidemic rate of 0.05 (r = 0.05); the putative economic threshold level of 5.80% (1.72%/ha/yr); the epidemic costs of GHC 2 229.86 ($ 202.71) FFB loss/Ha/Yr; and GHC 3 262.73 ($ 296.61) CPO loss/ha/yr, are four major contributions to the study of Ganoderma butt rot of oil palm in Ghana.

Hopefully, it will elicit the commensurate response form the major stakeholders in the oil palm plantation and industry in Ghana for sustainable management of the disease in Ghana. The sustainable management of Ganoderma butt rot in Ghana is crucial, because even at the present relatively low percntage annual GBR incidence per hectare (% DI) of 0.86 %/ha/yr and annual GBR epidemic rate per hectare (r) of 0.05/ha/yr, respectively, the economic costs (ec) are substantial. Depending on the range epidemic factors, the epidemic cost may rise exponentially, or at the very least, linearly with the epidemic rate of the disease.

The government of Ghana, commercial oil palm estates, smallholder farmers, oil palm millers and palm oil traders, agricultural research scientists, scholars and all who matter, should lend a hand to forestall or at the very least, enhance our competence and preparedness to contain potential GBR epidemic in Ghana.

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References

[1] CSIR-OPR Newsletter (202I)**.** Evolution of Oil Palm Industry: CSIR-Oil Palm Research Institute Leads Way. < info@ oilpalmresearch.org>. accessed 15 October, 2025.

[2] Ministry of Food and Agriculture (MoFA, 2023)**.** Master Plan Study on the Oil Palm Industry in Ghana: MASDAR Report. < [mofa.gov.gh]> accessed 15 October, 2025.

[3] Rhebergen, T., Fairhurst, T., Zingore, S., Fisher, Myles, Oberthur, T., Whitbread, A. (2016). Climate, soil, and land-use based suitability evaluation for oil palm production in Ghana. *European Journal of Agronomy* (81); p.1-14.

[4] Danso, I., Nuertey, B.N., Andoh-Mensah, E, Osei-Bonsu, A, Asamoah, T.E.O., Dwarko, D.A., Okyere-Boateng, G., Marfo-Ahenkora, E & Opoku, A. (2008). Response of oil palm to planting density and water deficit in three climatic zones of southern Ghana. *Journal of Ghana Science Association, 10*(2), p. 93.

[5] Danyo, G. (2013a). Commercial Oil Palm Cultivation in Ghana: An Outline. *Projournal of Agricultural Science Research*, 1(3), p. 22.

[6] Danyo, G. (2022). Epidemiology, Epidemic Cost and Management of Cape Saint Paul Wilt of Coconut in Ghana. Book Publisher International, UK., 2022.

[7] Karsten, P. (1881). Enumeratio Boletinearum et Polyporearum Fennicarum, Systemate novo dispositarum. *Revue de Mycologie* 3, p. 16.

[8] Moncalvo, J.M., and Ryvarden, L. (1997). A nomenclatural study of Ganodermataceae Donk. – *Synopsis Fungorum* 11, p. 1.

[9] Robinson, R.K. (1967). Ecology of Fungi. The English Universities Press Limited, St. Paul's House, Warwick Lane, London EC 4, p. 28.

[10] Bhosle, S., Ranadive, K., Bapat, G., Garad, S., Deshpande, G., Vaidya, J. (2010). Taxonomy and Diversity of *Ganoderma* from the Western parts of Maharashtra (India). *Mycosphere* 1(3), 249–262.

[11] Arif, M. S., Roslan, A., and Idris, A. S. (2011)**.** "Economics of oil palm pests and disease and yield losses," In: *Proceedings of the Third MPOB-IOPRI International Seminar: Integrated Oil Palm Pests and Diseases Management*, Kuala Lumpur, Convention Centre, Kuala Lumpur, Malaysia.

[12] Venkatarayan, S. V. (1936). The biology of *Ganoderma lucidum* on areca and coconut palms. *Phytopathology* 26, p. 153.

[13] Susanto, A., Sudharto, P.S., and Purba, R.Y. (2005)**.** Enhancing biological control of basal stem rot disease (*Ganoderma boninense*) in oil palm plantations. *Mycopathologia* 192, p. 153.

[14] Adaskaveg, J.E., Blanchette, R.A., and Gilbertson, R.L. (1991)**.** Decay of date palm wood by white-rot and brown-rot fungi. *Canadian Journal of Botany* 69, p. 615.

[15] Schwarze, F.W.M.R., Londsdale, D., and Mattheck, C. (1995). Detectability of wood decay caused by *Ustulina deusta* in comparison with other tree-decay fungi. *European Journal of Forest Pathology* 25, p. 327.

[16] Jong, S.C., and Birmingham, J.M. (1992). Medicinal benefits of the mushroom *Ganoderma*. *Advances in Applied Microbiology* 37, p. 101.

[17] Pornsuriya, C., Sunpapao, A., Srihanant, N., Worapattamasri, K., Kittimorakul, J., Phithakkit, S., and Petcharat, V. (2013). "A survey of diseases and disorders in oil palms of Southern Thailand," *Plant Pathology Journal*, 12 (4), p. 169.

[18] Kandan, A., Bhaskaran, R. B. and Samiyappan, R. C., (2010). Ganoderma – A basal stem rot disease of coconut palm in South Asia and Asia pacific regions. *Archives of Phytopathology and Plant Protection.* 43 (15), p. 1445.

[19] Ariffin, D., Idris, A.S., and Singh, G. (2000). Status of *Ganoderma* in oil palm. In: *"Ganoderma Diseases of Perennial Crops"* (J. Flood, P.D. Bridge and M. Holderness, eds.), pp 49-68. CAB International, Oxon, UK.

[20] Danyo, G. (2010). *Ganoderma* butt rot of Oil Palm. *Annual report*. Oil Palm Research Institute, Kusi, Ghana.

[21] Singh, G. (1990). "*Ganoderma*—the scourge of oil palm in coastal areas," *The Planter*, 67 (786), p. 421.

[22] Tengoua, F. F., and Bakoume, C. (2005). "Basal stem rot and vascular wilt; two threats for the oil palm sector in Cameroon" *The Planter*, 81, p. 97.

[23] Flood, J., & Hasan, Y. (2004). "Basal stem rot taxonomy, biology, epidemiology, economic status and control in Southeast Asia and Pacific Islands", In: *Proceedings of the International Conferenceon Pests and Diseases of Importance to the Oil Palm Industry, Fostering Global Cooperation in Instituting Quarantine Shield*, Kuala Lumpur, Malaysia, May 2004.

[24] Susanto, A. (2009, November). "Basal stem rot in Indonesia. Biology, economic importance, epidemiology, detection and control,". In: Proceedings of International Workshop on Awareness, Detection and Control of Oil Palm Devastating Diseases, Kuala Lumpur Convention Center, Kuala Lumpur, Malaysia.

[25] Palanna, K. B., Shreenivasa, K. R., Basavaraj, S. and Narendrappa, T. (2017b). Review of Genus *Ganoderma* causing Basal Stem Rot (Coconut) and Foot Rot (Arecanut) with Respect to Etiology and Management. *Int. J. Curr. Microbiol. App. Sci. 9(4)*: 1434-1455.

[26] Hanafi, C.N.A., Idris, M.M., Abdullah, A.S., Hasmah, S. N. A., Mohidin, H., and Rebitanim, N.Z. (2020). GanoCare®Improves Oil Palm Growth and Resistance against *Ganoderma* Basal Stem Rot Disease in Nursery and Field Trials. Hindawi BioMed Research International Volume 2020, Article ID 3063710, 16 pages.

[27] Kranz, J. (1990b). Epidemics, their mathematical analysis and modelling: An Introduction. In: Epidemics of Plant Diseases: Mathematical Analysis and Mo deling, 2nd Edn. (J. Kranz, editor). Springer, Berlin, pp.1-11.

[28] Neher, D.A., & Campbell, C.L. (1994). Nematode communities and microbial biomass in soils with annual and perennial crops. Applied soil ecology, 1(1), 17-28.

[29] Abdullah, F., Ilias, G. N. M., Nelson, M., Nur Ain Izzati, M. Z., & Umi Kalsom, Y. (2003). Disease assessment and the efficacy of *Trichoderma* as a biocontrol agent of basal stem rot of oil palms. *Research Bulletin Science Putra, p.* 1131.

[30] Tree Crops Development Authority (2026). Producer Price Index. Available at: https://www.tcda.gov.gh.

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