

Ecology of Basal Stem Rot Disease of Oil Palm (*Elaeis guineensis* Jacq.) in Cameroon

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Abstract: Basal stem rot (BSR) disease caused by species of *Ganoderma* is of immense importance in oil palm production. Although much is known on the occurrence of this devastating disease, fundamental studies on the ecology in oil palm in plantations are rather limited. This study sought to determine the incidence, severity, distribution and spread pattern of BSR disease in oil palm plantations and relate disease parameters to climatic and edaphic factors. Surveys were carried out for two years on two-hectare plots in each of five oil palm estates of the Cameroon Development Corporation. Data for disease incidence and severity in each estate were recorded. Disease spread patterns were generated from Arc GIS version 9.3 using GIS coordinates of diseased plants. A correlation between disease parameters and soil physicochemical properties and multivariate analyses were done. Typical BSR disease symptoms were observed including unopened spear leaves, skirt-like appearance of leaves, basidiocarp formation, bole creation and death of the palm. The disease incidence ranged from 5.4% in 16-year old palms at Bota to 39.0% in palms of the same age in Mungo where about 50% of infected plants had extreme severe symptoms. Although principal component analysis showed that six soil properties account for variation in BSR disease incidence and severity, only fine sand content was positively correlated ($P \leq 0.05$) with disease incidence and severity, while C/N ratio was negatively correlated. This study has established the occurrence and spread of basal stem rot disease in five oil palm plantations in South Western Cameroon.

Keywords: Epidemiology, Incidence, Severity, Spread Pattern, *Ganoderma*

1. Introduction

Oil palm, *Elaeis guineensis* Jacq is an important oil crop in Cameroon where over 230,000 tons of crude palm oil is produced in about 190,000ha [1]. In the past, production was based on the Dura type palm whose production was low, but with the development of plantation agriculture, the more productive Tenera hybrid is widely cultivated. This hybrid produces up to eight times the amount of oil produced by other vegetable oil seeds like soybean and sunflower [2]. The inflorescence is also tapped for the much cherished palm wine.

Generally, oil palm suffers from relatively few important diseases in each of the different environments where it has been planted commercially. In Southeast Asia, basal stem rot (BSR) disease caused by species of *Ganoderma* is the most important disease of oil palm [1]. Although in several African countries, vascular wilt caused by *Fusarium*

oxysporum f.s. *elaeidis* was thought to be the only disease causing serious problems in some plantations, BSR disease has become one of the major diseases of oil palm, especially in Cameroon [4]. The disease was first recorded in Malaysia where it was initially considered a disease of older palms as it occurred in palms of over 25 years [5]. The BSR disease has also been recorded in Malaysia, Indonesia, Nigeria, Ghana, Zaire, Angola, Tanzania, North Mozambique, Papua New Guinea and Cameroon [5,6]. The causal agent of basal stem rot disease in Malaysia was first identified as *G. lucidum* (W. Curt.) Karst [5]. At least seven species of *Ganoderma* have been associated with BSR of oil palm in Malaysia, Indonesia, Papua New Guinea and Cameroon including *G. boninense* Pat., *G. miniatocinctum* Steyaert, *G. chaliceum* (Cooke) Steyaert, *G. tornatum* (Pers.) Bers., *G. zonatum* Murill, *G. xylonoides* Steyaert, *G. ryvardense* Tonjock and Mih and *G. lobenense* [7, 5, 6, 8, 9]. BSR disease has been found to infect oil palms as young as 1 to 2 years of age, and is serious on palms aged 4 – 5 years

of age, particularly in replanted areas [10]. In new oil palm planted from jungle or old rubber plantations, BSR incidence of 25% has been recorded after 25 years while in that planted from old coconut plantations, an incidence of 60% occurred after 16 years [11], whereas oil palm to oil palm under planting has resulted in 33% infection after 15 years. The highest disease incidence is in coastal areas [5, 12]. In Malaysian coastal areas, a 50% loss of yield was recorded from 80% disease incidence on 13 year old plantings [13]. A survey has also reported typical levels of disease incidence of 30% on 13 – year old palms in both inland and peat soils [14]. In North Sumatra (Indonesia), by the time of replanting (25 years) 40 – 50% of palms are lost in some fields with the majority of standing palms showing disease symptoms. Where oil palm stumps were left in the ground at replanting then more serious palm losses due to *Ganoderma* have been observed in some fields with up to 25% incidence that occurred within 7 years [15].

The natural infection with *Ganoderma* in oil palm occurs as a result of contact between healthy roots and diseased tissues left buried in the soil [16]. Subsequent spread occurs by root to root contact once a few palms are infected [17].

In young palms, the external symptoms of basal stem rot normally comprise a one sided yellowing, or mottling of the lower fronds, followed by necrosis [10]. The newly unfolded leaves are shorter than normal and chlorotic, and additionally the tips maybe necrotic. As the disease progresses within the plant, the diseased palm may take on

an overall pale appearance, with retarded growth and the spear leaves remain unopened [10]. Affected leaves die, necrosis sets in, beginning with the oldest leaves and extending progressively upwards through the crown. Dead dessicated fronds droop at the point of attachment to the trunk or fracture at some point along the rachis and hang down to form a skirt of dead leaves.

Although there have been sporadic reports of basal stem rot in Cameroon, there is no comprehensive study on the ecology of the disease that could guide its management. The objectives of this work was therefore to determine the incidence, severity, distribution and spread pattern of basal stem rot disease in south western Cameroon and see how the disease relates to climatic and edaphic factors.

2. Materials and Methods

2.1. Establishment of Sampling Plots

The ecology of basal stem rot was studied in five oil palm estates belonging to the Cameroon Development Corporation (CDC) in south western Cameroon (Fig. 1). The means of various environmental parameters are shown on Table 1.

In each estate, four 2ha plots were mapped out, each of the same age as shown on Table 2. Location of plot was done through a stratified random sampling technique.

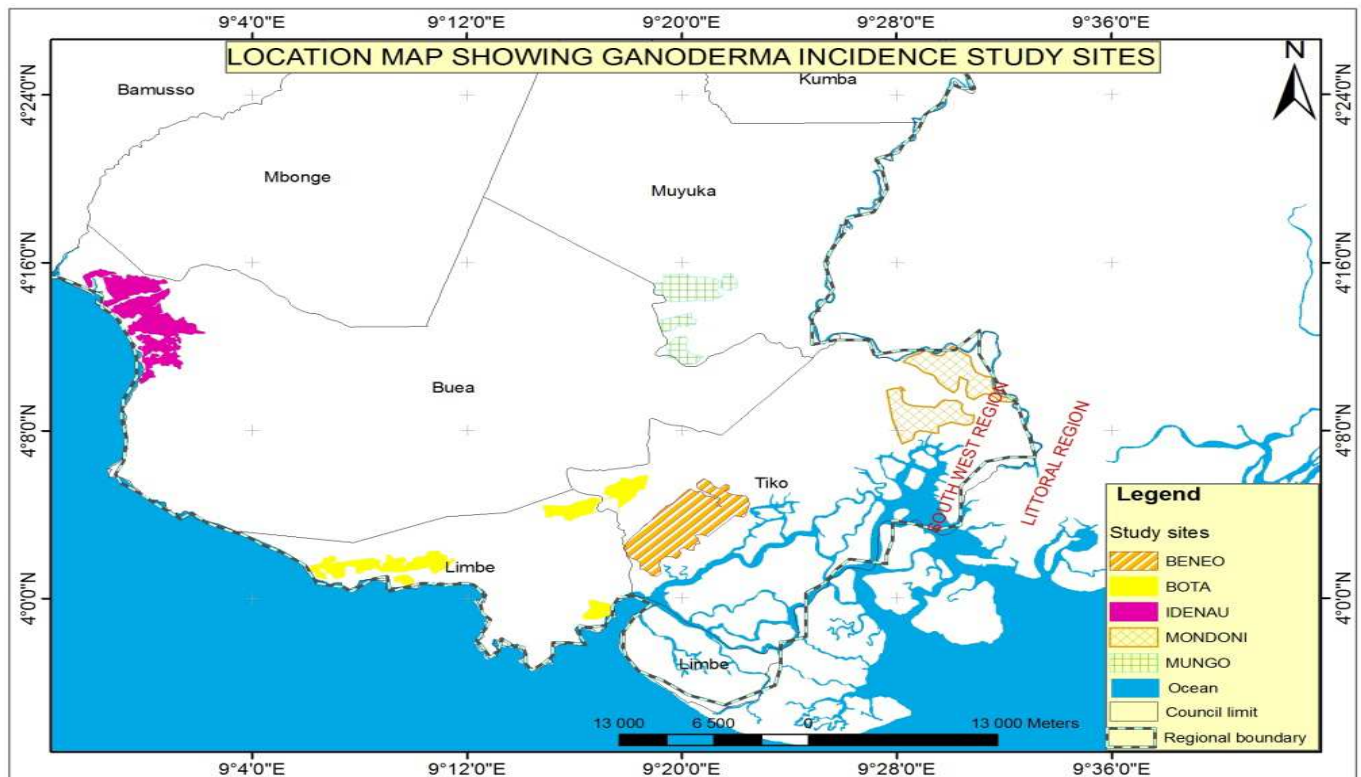


Fig. 1. Survey sites of basal stem ro disease of oil palm in south western Cameroon.

Table 1. Mean environmental parameters for five oil palm estates surveyed for basal stem rot disease in south western Cameroon.

Descriptors	Sites				
	Beneo	Bota	Idenau	Mondoni	Mungo
Location(Lat (N)	N 05° 38 28.6'	N04° 00 908'	N04° 14.949'	N04° 10.483'	N04° 14.813'
Long (E)	E04° 50 91.2'	E009° 09.659'	E009° 00.059'	E009° 25.361'	E009° 23.895'
Altitude (m)	62–72	50–72	42–80	24–39	44–60
Max.Temp (°C)	28.4	30	31	33	32
Min. Temp (°C)	22.1	20.6	22	23.3	22.9
Rainfall (mm)	2803	4927.6	6899.7	2306.1	1636.8
Rainfall days	145.7	182.8	221.5	135.8	100.4
Rel. humidity (%)	84.9	86.9	85.5	84.8	85.4
Sunshine days	309	280	280	297	261
Sunshine hours	1427	1133	1129	1334	1122
Soil	Clay loam	Volcanic	Volcanic	Sandy loam	Sandy

Table 2. Age of sampling plots for basal stem rot disease in five oil palm estates of south western Cameroon.

Estate	Year of planting	No. of plots	No. of plants
Beneo	1995	1	286
	1973	1	286
Bota	1996	2	572
	1978	2	572
Idenau	1973	1	286
	1995	1	286
Mondoni	1995	1	286
	1996	1	286

2.2. Disease Scoring

Each plant in the sampling plots was observed for symptoms of BSR during the wet (June – August) and dry (October – December) seasons of 2010 and 2011 respectively, and scored for BSR severity on a scale of 0 – 4 as shown on (Table 3) according to the method of Abdullah *et al.* [18].

Table 3. Scoring scale for basal stem rot disease of oil palm.

Severity class	Description
0	Healthy looking plants with green leaves without appearance of fungal mycelium on any part of plants.
1	Appearance of white fungal mass on any part of plants, with or without chlorotic leaves and unopened spear leaves at the centre.
2	Appearance of basidiomata on any part of plants with chlorotic leaves, skirt-like appearance of the leaves resulting in collapse of the lower leaves.
3	Formation of well-developed basidiocarp and bole creation.
4	Death of the plant and creation of bare land.

Adapted from Abdullah *et al.* [18]

The disease incidence was calculated as follows;

$$I = \frac{\text{No.of plants with score 1-4}}{\text{No.of plants observed}} \times 100\% \quad (1)$$

Where I= Incidence

To assess the severity of the BSR disease, the disease severity index (DSI) was calculated using the method of Abdullah *et al.* [18] thus:

$$DSI = \frac{\sum AB}{4 \sum B} \times 100\% \quad (2)$$

Where:

A – Disease class (0, 1, 2, 3 or 4)

B – Number of plants showing that disease class per estate.

The Geographical Positioning System (GPS) point of each symptomatic plant was recorded. The data were processed using arc GIS version 9.3, to generate the disease spread pattern map.

2.3. Soil Sampling and Analysis

For each of the estates surveyed, five core soil samples were collected at a depth of 0 –10 cm, bulked, mixed thoroughly, air dried and sieved through a 2mm sieve. Sub samples were then analysed for physicochemical properties according to the method of Anderson and Ingram [29] at the soil science laboratory of IRAD Nkolbisson, Yaounde, Cameroon. Water holding capacity (WHC) was determined in the Life Sciences Laboratory at the University of Buea. Five replicate samples per site (Mungo, Mondoni, Beneo, Bota and Idenau) were each saturated with tap water and weighed, (w_1). The weighed samples were each dried at 70°C to a constant weight, w_2 . The WHC was estimated as follows:

$WHC = \frac{w_1 - w_2}{w_2} \times 1000 \text{ mL kg}^{-1}$ (Assuming the density of H₂O = 1 g/mL) The relationship between BSR disease and other environmental parameters was determined by multivariate analyses (correlation and principal component analysis, PCA) using MINITAB version 16.

3. Results and Discussion

Both asymptomatic and symptomatic plants of various levels of severity were observed in the field. Symptoms observed in the field are shown on Fig. 2. These ranged from presence of multiple unopened spear leaves at the centre, to skirt-like appearance of the leaves. Generally, the symptomatic palms had a pale appearance. Other symptoms observed were, production of fruiting bodies, bole creation on the base of the trunk, and finally death of the palms. The symptoms were typical of those described for the disease [19]. These are different from symptoms of vascular wilt of

oil palm in that there is dryness of the lower leaves, the breaking of the rachis at about one third the length from the trunk, the hanging of the dry leaves along the trunk for the typical or acute form, the narrowing of the trunk at the top taking a “pencil – point” appearance, and the cracking of the trunk resulting from deterioration of the vessels for the chronic form [20, 4]. During the first year of observation, the incidence ranged from 4.6% in Beneo estate to 38.0% in 16 year old palms at the Mungo estate (Table 4). The incidence was generally high in young palms (≤ 16 years) when compared to old palms (>30 years) which recorded an incidence range of 14.2 – 20.7%. The second year of observation showed a general trend of increasing incidence from 6.8% in Bota to as high as 40.0% in Mungo. Considering the two years of observation, the average disease incidence was highest at Mungo in palms that are at about their peak production age. Except for Mungo, the incidence of basal stem rot was generally low when compared to

reports from other parts of the world on palms of comparable age. For example, values of 85% have been reported in 25 year old palms in Malaysia [21] and 30% in 13 years old palms in Malaysia [14]. The basal stem rot severity index was highest in Mungo where the mean for the period of observation was 80%, rated as very severe (Fig. 3). This is supported by the fact that the proportion of symptomatic plants with a score of five was highest there (Fig. 4). The high severity indices are an indication of the threat of this disease to production. Other observations on small holder fields in the Mungo area have similarly been shown to be highly infected, resulting in death of palms [1]. Basal stem rot disease spread showed a cluster pattern of spatial dispersion with only Bota showing a sparse pattern (Fig. 5). The disease had a dense cluster pattern in Mungo, Mondoni, Beneo, and Idenau estates. The spread pattern of BSR disease in this study was typical of soil-borne diseases which occurred in patches [22].

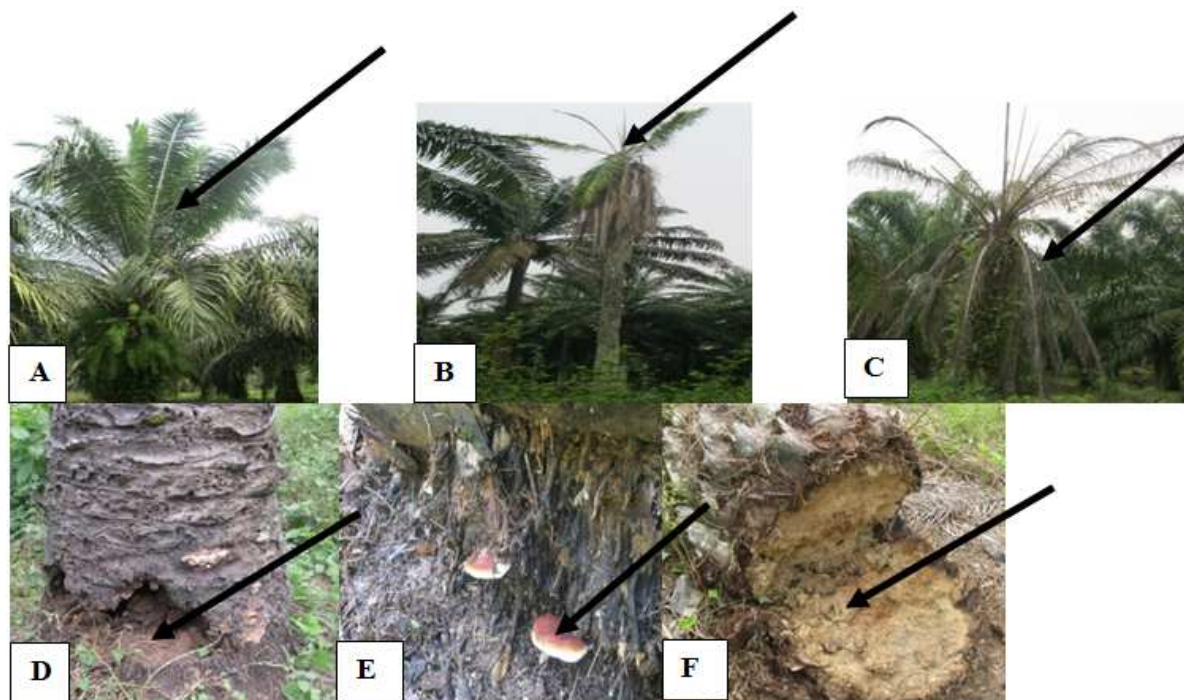


Fig. 2. Field symptoms of BSR disease of oil palm in plantations of the CDC. A) Asymptomatic plant, B) Unopened spear leaves at the centre, C) Skirt-like appearance, D) Basidiocarp formation, E) Bole creation, F) Death of palm.

Table 4. Incidence of basal stem rot disease in five oil palm plantations south western Cameroon.

Location	Year of plantings	Age at first observation (years)	Incidence (%)		
			Mean (2010 dry and wet seasons)	Mean (2011 dry and wet seasons)	Mean (2010 and 2011)
Beneo	1995	15	4.6	9.4	7.0
	1973	37	20.7	21.3	21.0
Bota	1996	16	5.9	6.8	5.4
	1996	16	9.4	10.2	9.8
Idenau	1978	32	14.2	14.8	15.0
	1978	32	18.3	19.7	19.0
Mondoni	1995	15	16.8	18.4	17.6
	1973	37	17.5	19.1	18.3
Mungo	1996	16	38.0	40.0	39.0
	1995	15	31.4	36.6	34.0

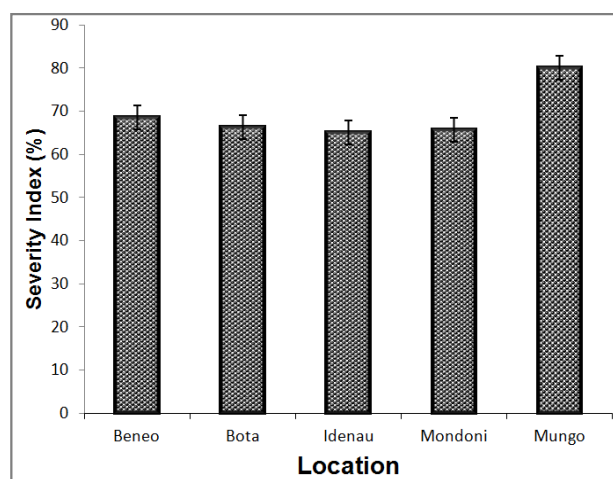


Fig. 3. Mean disease severity index of five oil palm estates in south western Cameroon.

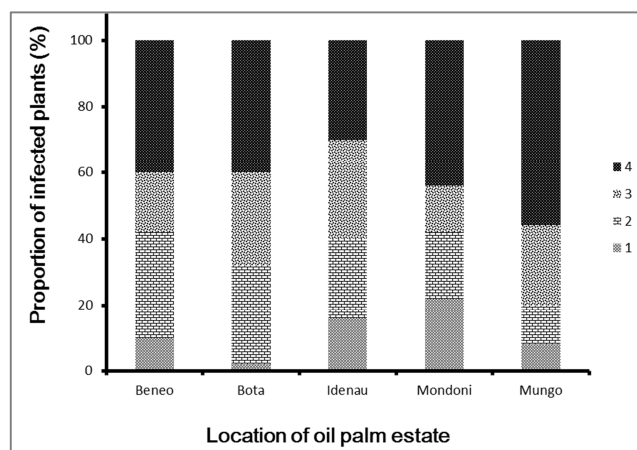


Fig. 4. Proportion of diseased plants in each disease score (mean of two years) in five oil palm plantations in south western Cameroon.

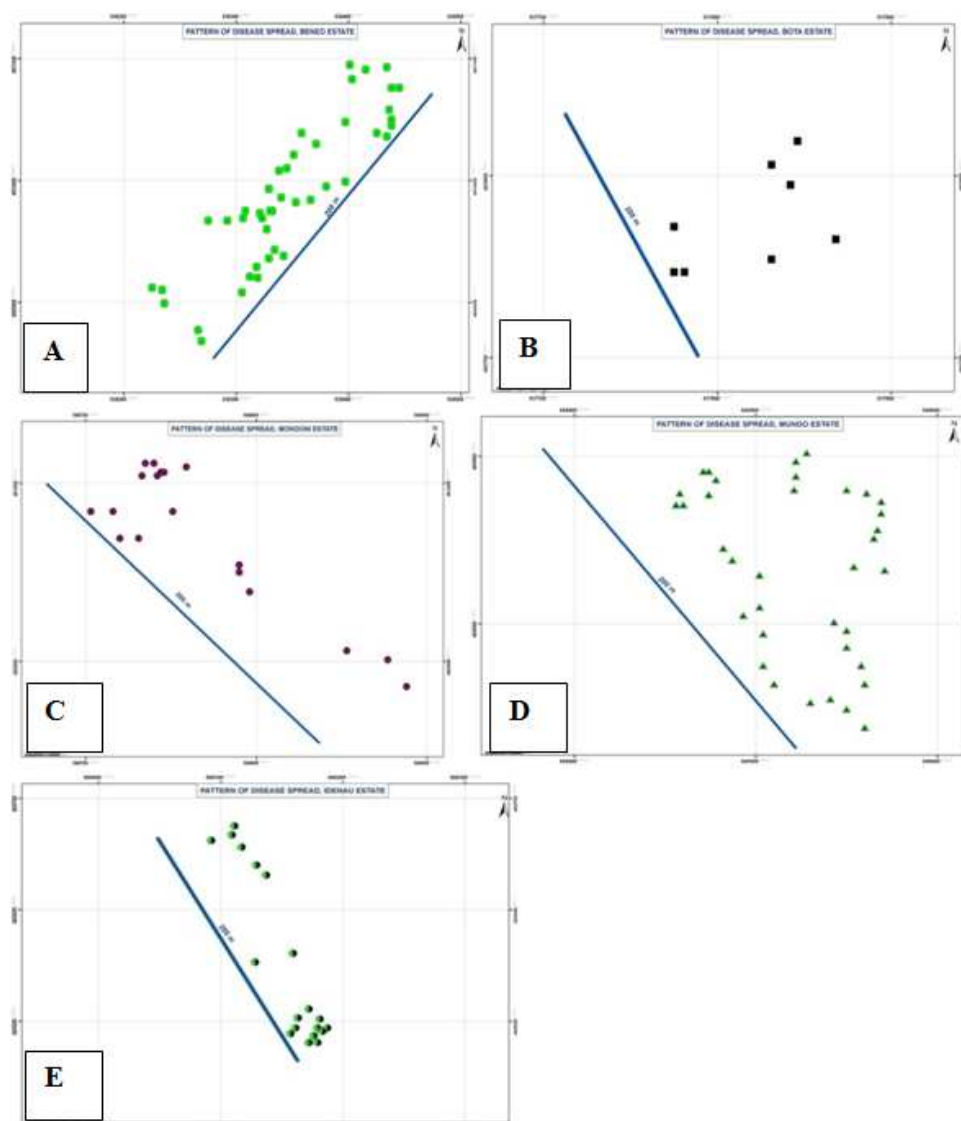


Fig. 5. Spread pattern of BSR disease in oil palm plantations in south western Cameroon. A) Beneo estate, B) Bota estate, C) Mondoni estate, D) Mungo estate, E) Idenau estate.

They typically appear in clusters or patches. The clustered pattern of infected plants was recorded at a number of sites and this was analogous to the pattern of basal stem rot reported by Rao *et al.* [14]. The mode of survival of *Ganoderma* as hyphae in oil palm residues would favour a clustered pattern of infected plants since dispersion of the residues of each plant would tend to overlap with that of other plants and a continuum of infested residue may result as the incidence of infected plants increases. Thus, under environmental conditions which favour a high incidence of infected plants, the pattern of infected plants would become regular. Soil physicochemical properties varied across the estates (Table 6). Of these properties, fine sand had a significant positive correlation with disease incidence and severity at 0.01 probability level, while C/N ratio had a significant negative correlation at 0.05% probability level. There was no significant correlation between any of the climatic factors and disease incidence. This does not preclude the indirect effect of climate through the vigour of the plant and soil. This observation is expected because the disease is soil borne and systemic. Results of the principal component analysis (PCA) showed that the first four principal components explained 100% of the total variation (Table 7). The PC₁ is strongly associated with fine silt, pH in KCl, organic carbon and total organic matter. PC₂ is strongly associated with pH in H₂O, base saturation and Sodium. PC₃ is strongly associated with total nitrogen, clay content, base saturation and fine sand, and PC₄ is strongly associated with coarse silt, moisture content, cation exchange capacity and water holding capacity (Table 8). The climatic data for Mungo was comparable to those of other sites. However, the edaphic factors were unique. The soils have a very high sand content, low clay content and consequently, low water holding capacity. The soil factors may partly contribute to this high incidence, given that there was a strong positive correlation between fine sand and incidence. Also, it may be due to the low nutrient status since there was a significant negative correlation between C/N ratio and disease incidence and severity. The low percentage of clay content of soil in Mungo estate might have been more conducive to the development of the basal stem rot disease than those with high clay contents. Soils low in clay content have been shown to be favourable to some soil borne diseases as is the case for damping-off of tomato seedlings caused by *Sclerotium rolfsii* in the Nigerian Savanna [23]. The incidence of basal stem rot would be much higher in future than the values obtained in the present survey because detection was based only on symptomatology. Plants at the early stages of infection generally do not manifest any symptoms. More elaborate techniques may be required to detect such plants [24].

Tengoua and Bakoume [4] recorded a 40% incidence level of basal stem rot in Mussaka palm plantation of the CDC planted between 1967 and 1969 but they actually projected a 60% incidence level of basal stem rot disease. However,

these were very old palms and their result was not comparable to the present result in terms of percentage disease incidence but it shows that this disease had been present in oil palm plantations of the CDC.

The high disease severity indices observed in the palms was expected. Plants with severity scores 3 and 4 constituted over 50% of the plants, thus resulting in the high disease indices observed. There was no management strategy put in place in the oil palm estates surveyed. The effects of the disease could easily be mitigated in Cameroon with proper management efforts. A preliminary survey in plantations of SOCAPALM where a rigorous eradication scheme was supplemented with trenching to curb spread revealed an extremely low incidence of less than 1%. However, in Malaysia a basal stem rot incidence of 80% and more were recorded in areas with attempted management strategies [14].

Fine sand was primarily the edaphic factor that influenced basal stem rot disease, having a significant positive correlation. High fine sand content (45.86%) found in Mungo estate allows for easy growth of roots thus enhancing contact and subsequent spread of basal stem rot. A very strong significant negative correlation was observed between incidence of basal stem rot and C/N ratio. Soils with low C/N ratios tend to release nutrients fast [25]. These nutrients easily leach away in the low water holding capacity soils thus starving plants and predisposing them to attack. Unsuitable soil conditions for plant development generally arise from lack of organic matter content in the soil [26, 27]. Higher content of easily decomposable organic matters might be associated with higher microbial activity and ultimately lead to the decline of *Ganoderma* species population. Thus higher population of *Ganoderma* may aggravate the disease situation in locations where soil reaction is more acidic and organic carbon content is less as in the case of Mungo estate. The lower disease incidence in other estates may be attributed to high organic carbon contents and weak acidity. Similar results were obtained by Sharma *et al.* [28] for ginger rhizome rot.

4. Conclusion

This study documents the first comprehensive study on the incidence, severity and associated factors of *Ganoderma* disease of oil palm in South Western Cameroon, after the initial report by Tengoua and Bakoume [4]. The incidence and severity of the disease shows that it is of increasing importance in oil palm production such that its management needs to be considered in the oil palm production plan, given that the disease is very devastating in Malaysia and other oil palm producing countries of the Indian sub – continent. The pattern of disease occurrence and distribution was attributed to variations in edaphic factors which are important in pathogen survival and host predisposition. Although there was no correlation between incidence and severity of BSR with climatic factors,

principal component analyses showed the indirect influence of climate on the disease. Although no resistant clones are known for the disease, seed producers in Cameroon should screen for resistance in different progeny crosses. Also, there is need to monitor the disease on a continuous basis.

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References

- [1] Nkongho R.N, Feintrenie L. and Levang P. (2014). *The Non-industrial Palm Oil Sector in Cameroon*. Working Paper 139, Bangor, Indonesia: CIFOR.
- [2] Jacquard JC (2012). *Le Palmier a l'huile*. Montpellier – France, Edition Quae, CTA, Presses agronomiques de Gembloux.
- [3] Naher N, Yusuf UK, Ismail A, Tan SG and Mondal MMS (2013). Ecological status of basal stem rot disease of oil palm. *Australian Journal of Crop Science* 7(11): 1723 – 1727.
- [4] Tengoua FF, Bakoume C (2005). Basal stem rot and vascular wilt, two threats for the oil palm sector in Cameroon. *The Planter* 81: 97 – 105.
- [5] Turner PD (1981) *Oil Palm Diseases and Disorders*. Kuala Lumpur, Oxford University Press, 281p.
- [6] Pilotti CA, Sanderson FR, Aitken AB, Armstrong W (2004). Morphological variation and host range of two *Ganoderma* species from Papua New Guinea. *Mycopathologia* 158: 251 – 265.
- [7] Steyaert RL (1967). *Les Ganoderma palmicoles*. *Bulletin du Jardin Botanique Nationale Belgique* 37: 465 – 492.
- [8] Kinge TR, Mih AM (2011) *Ganoderma rywardense* sp. nov. associated with basal stem rot disease of oil palm in Cameroon. *Mycosphere* 2 (2): 179 – 188.
- [9] Kinge TR and Mih AM (2014). *Ganoderma lobense* (Basidiomycete), a new species from oil palm (*Elaeis guineensis*) in Cameroon. *Journal of Plant Sciences* 2 (5):242 – 245.
- [10] Singh G (1990). *Ganoderma* the scourge of oil palms in the coastal areas. In: Ariffin, D. and Jalani, S. (editors) *Proceedings of Ganoderma workshop*, 11 September 1990 pp113 – 131. Palm Oil Research Institute of Malaysia, Bangi, Selangor, Malaysia.
- [11] Singh G (1991). *Ganoderma* the scourge of oil palms in the coastal areas. *The Planter* 67:421 – 444.
- [12] Khairudin H (1990). Results of four trials on *Ganoderma* basal stem rot of oil palm in Golden Hope Estates. In: Ariffin, D. and Jalani, S. (eds) *Proceedings of Ganoderma Workshop*, 11 September 1990, pp 113 – 131. Palm Oil Research Institute of Malaysia, Bangi, Selangor, Malaysia.
- [13] Lim TK, Chung GF, Ko WH (1992). Basal stem rot of oil palm caused by *Ganoderma* infection in the field. *Mycopathologia* 159: 101 – 107.
- [14] Rao V, Lim CC, Chia CC, Teo KW (2003) Studies on *Ganoderma* spread and control. *The Planter* 79: 367 – 83.
- [15] Subagio A, Foster HL (2003). Implications of *Ganoderma* disease on loss in stand and yield production of oil palm in North Sumatra. In: *Proceedings of the MAPPS Conference* (Aug 2003). Kuala Lumpur.
- [16] Sanderson FR, Pilotti CA, Bridge PD (2000). Basidiospores: their influence on our thinking regarding a control strategy for basal stem rot. In: Flood, J., Bridge, P. D., Holderness, M. (Eds.), *Ganoderma Diseases of Perennial Crops*. CABI Publishing, Wallingford, UK, pp. 113 – 119.
- [17] Flood J, Bridge PD, Holderness M (2000). *Ganoderma Diseases of Perennial Crops*. CABI Publishing, Wallingford, UK. pp32.
- [18] Abdullah F, Ilias GNM, Nelson M, Nur Ain Izzati MZ, Umi KY (2003). Disease assessment and the efficacy of *Trichoderma* as a biocontrol agent of basal stem rot of oil palms. *Research Bulletin Science Putra* 11: 31 – 33.
- [19] Abdul RJH, Ahmad K, Ramdhan AS, Idris S, Abdul R, Aminul R, Fauzi I (2003). Mechanical Trunk Injection for Control of *Ganoderma* MPOB Information Series. MPOB TT No. 215.
- [20] Hartley CWS (1988). *The Oil Palm*. Third edition, Harlow, England: Longman.
- [21] Gurmit S (1990). *Ganoderma*– The scourge of oil palms in the coastal areas. P7–35. In: *Proceedings of the Ganoderma Workshop*, 11 September. (edited by Ariffin D and Jalani S) Palm Oil Research Institute of Malaysia. P1 – 142.
- [22] Agrios GN (2005) *Plant Pathology* 5th edition. Elsevier Academic Press. 901pp.
- [23] Wokocha RC (1987). Effect of Soil type on the damping-off of tomato seedlings caused by *Sclerotium rolfsii* in the Nigerian Savanna. *Plant and Soil* 98(3): 443 – 444.
- [24] Ishaq I, Alias MS, Kadir J and Kasawani I. (2014). Detection of basal stem rot disease at oil palm plantations using sonic tomography. *Journal of sustainable science and Management* 9(2): 52 – 57.
- [25] Myers RJK, Palm CA, Cuevas E, Gunatilleke IUN, Brossard M (1993). The synchronization of nutrient mineralization and plant nutrient demand. In: Woomer P. L., Swift, M. J., (Eds.). *The biological management of tropical soil fertility*. TSBF– John Wiley and Sons, Chichester, UK.
- [26] Boyle M, Frakenburge, WT, Stolyz LH (1989). The influence of organic matter on soil aggregation and water infiltration. *Journal of Production Agriculture* 2: 290 – 299.
- [27] Tejada M, Hernandez MT, Garcia C (2006). Application of two organic amendments on soil restoration: Effects on the soil biological properties. *Journal of Environmental Quality* 32: 1010 – 1017.
- [28] Sharma BR, Dutta S, Roy S, Debnath A, Roy DM (2010). The effects of soil physico-chemical properties on Rhizome rot and wilt disease complex incidence of ginger under hill agro-climatic region of west Bengal. *Plant Pathology Journal* 26(2): 198 – 202.

- [29] Anderson JM, Ingram JSI (1993) Tropical Soil Biology and Fertility: a handbook of methods Second edition. CAB International, the Camrian News, Aberstwyth, United Kingdom, 221pp.