PROBLEMS OF *ARMILLARIA* ROOT AND BUTT ROT IN TROPICAL AFRICA: THE CASE OF NIGERIAN FORESTS.

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ABSTRACT

Armillaria root and butt infections of plants have been the cause of substantial economic losses in a number of cash crops and other plants of horticultural importance throughout the African continent. As in most tropical countries, research into problems resulting from *Armillaria* infections has gone through an evolutionary process. This paper examines the various developments that have taken place and recent contributions aimed at solving problems resulting from the menace of *Armillaria* on economic crops in tropical Africa. The result of a field study carried out in Nigeria forests to ascertain the current situation of *Armillaria* is also presented and discussed.

Keywords: Armillaria, root rot, tropical Africa, Nigeria

INTRODUCTION

Armillaria mellea (Vahl ex Fr.) Kummer is well known as a root-rot pathogen of many species of woody and herbaceous plants worldwide. While many species simply decay dead roots and wood, others infect and kill living trees and other plants with woody or starchy roots. Up to 30% losses have been reported as a result of *Armillaria* infection on Cassava farms in Zimbabwe (Mwenje *et al*, 1998). Typically, an attack by *Armillaria* results in a severe white rot in the roots that often spread to the butt. Losses of amenity and economic trees due to *Armillaria* are important in Britain, (Rishbeth, 1983); USA (Wargo, 1985); Australia (Kile, 1983), Sao Tome, (Rishbeth, 1980) Garbon, (Guyot, 1997); Kenya (Onsando *et al*, 1997) Nigeria, (Fox, 1964); Congo (Makambila *et al*, 1994), Zimbabwe (Masuka, 1989) and other parts of the world.

The ability of the pathogen to attack a living plant as a parasite or act as a saprophyte on dead plants is often attributed to its ability to utilise stress of host plant to its advantage to manifest infection. It is therefore often regarded as 'an opportunist' (Wargo, 1980). This aspect of this behaviour of *Armillaria* has been extensively studied (Wargo and Houston, 1974; Popoola and Fox, 1996; Popoola and Fox, 2003a, Popoola and Fox 2003b, Popoola and Fox, 2003c) in various parts of the world.

The menace of *Armillaria* root and butt rot is of serious concern in Europe, Australia, America and other developed nations of the world. Research into the biology, morphology, taxonomy, aetiology and ecology of *Armillaria* in these continents has been on for several decades. This is with a view to finding a workable control measure to the devastating problems caused by this pathogen on economic crops.

However, relatively little has been done in tropical Africa. The general status of *Armillaria* as a pathogen in Africa was best described in the 1960's and 1970's. Notable researchers of this period such as, Dadaut, (1963), Gibson (1964), Goodchild (1960) Swift (1964) and Blaha (1978)considered *Armillaria* as having reached economic importance status in Southern, Central, Western and Eastern Africa, because of the damage done to softwood timbers (pines), tea, tung, coffee and cocoa

This paper examines the trend of research, the nature of the problem as well as recent findings on the prevalence of the diseases of *Armillaria* in tropical Africa with particular reference to the Nigerian forest situation.

Pre-independence years

Since the realisation of the role of *Armillaria mellea* as the causal fungi of root and butt rot of many plants of economic significance. Plant pathologists, mycologists, taxonomists and other concerned scientists in related fields have not relented in their efforts in finding solutions to the devastating damages caused by this fungus.

In the past few decades, the contributions of Dr. John Rishbeth (late), Dr. Roy Watling, Steve Gregory, Derek Redfern and Roland Fox in the United Kingdom. Philip Wargo, C.G Shaw III, Roy Whitney in North America, Korhonen in Finland, J. J.Guillaumin and Caroline Mohammed in France, to mention a few has tremendously given a lot of encouragement to solving the puzzle behind the various aspects of studies on *Armillaria*. More recently, scientists from different parts of the world are showing further interest in *Armillaria* studies. Africa South of the Sahara is not left out.

In Africa, up till the late nineteen twenties, most of the experimental works on plantation crops were carried out by Agricultural Departments of European Colonies which were scattered all over Africa South of the Sahara. Despite the various difficulties, enormous progress was made. The reports of Dade (1927), on Cocoa in West Africa, Butler (1928), Leach (1937, 1939) in Malawi; Weiche, (1952), Fassi (1959), Gibson, (1960), Gibson & Corbett (1964), Fox (1964) and Olembo (1972) were some of the pioneering studies on *Armillaria* in Africa. The reports of these scientists were well documented and were done in collaboration with forest pathologists and mycologists in other parts of the world particularly France and the United Kingdom.

Eady G.H. in 1922 (Fox, R.A., *pers. Comm.)* first reported the presence of collar crack disease on cocoa in the then Togoland. The outbreak of this disease gave government serious concern that legislation was instituted for its control. This disease later surfaced in the then Gold Coast (now Ghana) in West Africa. A similar report was made by Small (1923) in Uganda.

According to Dade (1927), "collar crack" was used to describe the disease being an apt description of the most evident and characteristic symptom of the disease. Using reports of R.H. Bunting (Fox, R.A. *pers. comm*) and other workers in the British Colonies in West Africa, Dade (1927) gave a detailed description of the symptoms, aetiology and control measures. The omnivorous parasitism in addition to the saprophytic habit of the organism made eradication of the fungus from farms surrounded by bush increasingly difficult. *A. mellea* was therefore classified as an injurious pest in the plants (Injurious Pest) Ordinance of 1924. (Anon, 1924). Failure on part of a farmer, who fails to maintain good sanitary condition and apply the `prescribed treatment' to cases of attack was considered an offence punishable by fines or imprisonment. This was to show the importance of the menace of the disease on the economy of Ghana. Although various therapeutic treatments of infected trees were not usually possible, the application of antiseptic and protective paint, treatment with Bordeaux paste (Copper Sulphate in water) gave temporary protection.

It is not to say that, Cocoa was the only plant susceptible to *Armillaria* infections. Kola (*Cola acuminata*), *Terminalia* spp., Elephant grass (*Pennisetum purpureum*) Oil-palm (*Elais guineesis)*, Lime (*Citrus* sp), Mango (*Mangifera indica)*, Cassava (*Manihot esculenta*), Coffee (*Coffea arabica*), Okra (*Hibiscus esculentus*), and Pepper (*Capsicum* spp) were also infected and listed by Dade (1927). Apart from the comprehensive reports of the disease in Ghana, there were also reports of losses of economic plants due to *Armillaria* root rot in other parts of Africa. In North Africa, losses were recorded on fig trees. Butler (1928) recorded similar attacks on tea (*Camella sinensis)* in Malawi.

Of importance during this era was the report of Dade (1927) on Collar crack of Cacao in Ghana. He concluded that (1) Collar crack of Cacao caused by *Armillaria mellea* was very destructive and rapidly spreading and widely distributed throughout the forest belt of Ghana (2) That the causative fungus is a virulent parasite not depending on wounding of previous infections for entry into host (3) Transmission is by root contact. (4) Humidity was the significant environmental factor correlated with severity of attack. (5) Control is by reduction of humidity of infected plants.

Post Independence Years

More studies were carried out on *Armillaria* from Africa in the post independence era. Initial difficulties which workers in tropical countries faced with regards to making contact with their colleagues in the temperate countries slowed down pace of work. This was later overcome, as more studies were carried out with isolates from Africa, which had been deposited at Kew and similar institutions in France. Visits were made to plantations in West and East Africa to update research reports and to substantiate results of laboratory studies.

Gibson and Corbett (1964), noted losses due to *Armillaria* root rot disease on tea and forest crops including pines. Also, in Nigeria, Fox (1964) described symptoms of infection of *Armillaria* on rubber plantations in South Eastern parts of the country. Some of the hosts listed as susceptible hosts of *Armillaria* in Nigeria and other parts of Africa correspond with those listed by Raabe (1962) for economic crops in other parts of th world

Thorold (1975) listed reports of attacks in nine West African countries. Fox (1964) gave over 52 host of the fungus in Ghana, Congo and Nigeria. Rishbeth (1980) reporting on a visit to the Islands of Sao Tome and Principle in West Africa threw further light on the behaviour of *Armillaria* in tropical plantations. He confirmed absence of rhizomorphs formation and linked this with altitude. No rhizomorphs were found in soil, roots and sites at up to an elevation of 1000m. However, in Kenya, rhizomorphs may be found abundant at altitude of 2000m and above. The absence of rhizomorphs was attributed to the high soil temperatures and adverse conditions of soil aeration.

Cultural practice particularly digging of trenches proved useful in controlling spread of the disease in cocoa plantations. However, as effective as this approach was, it increased losses within the trenched areas. Closely related observations were made on *Hevea brasiliensis* plantations in Ivory Coast. Recently, additional information on the behaviour of African *Armillaria* were provided by Makambila (1994), that root rot caused by *A. heimii* in the tropics is a problem yarning for solution.

Pathology

Like the biological species of *Armillaria* described for North America, Australia and Britain, differences have been reported in the pathogenicity of African *Armillaria*. British *Armillaria* species have been broadly grouped based on their pathogenicity and host preference. *A. mellea* attacks coniferous and deciduous trees and it's considered most virulent. *A. ostoyae* (formerly *A. obscura*) shows greater preference for coniferous trees while *A. lutea* (formerly *A. bulbosa*) is only pathogenic to weak young exotic shrubs and trees (Fox, 1990a, Fox, 1990b; Fox 2000). Although no such classification have been achieved for African *Armillaria*. Popoola and Fox (1989) observed that isolates of *Armillaria* from East and West Africa were more virulent in their pathogenic behaviour on Strawberry, Blackcurrant, Privet and Lawson cypress compared to isolates obtained locally from various sites in South East England. These African isolates also produced rhizomorphs profusely on 3% Malt Extract Agar medium. Mwenje & Ride (1998) also confirmed differences in the pathology of Zimbabwe isolates of *Armillaria* tested on cassava tubers. These observations confirmed the impression on differences in the pathogenicity of African *Armillaria,* compared to the English and American isolates.

Taxonomy & Morphology

Prior to the realisation that *A mellea* consist of different biological species. All infections due to *Armillaria* were attributed to *A. mellea*. Different biological species have however been described and recognised in North America, Europe and Australia. Similarly, morphologically different species have been described for African *Armillaria*, however, little is known of their status as biological species. Mohammed (1989) found genetic criteria to be of limited value in separating African isolates.

Mwenje & Ride (1996, 1997) used biochemical characteristics and pectic enzyme analysis to distinguish between European and African *Armillaria* isolates and concluded that isolates from Africa previously classified as *A. heimii* or *A. mellea* showed specific enzyme pattern.

Recently, several species of *Armillaria* have been described for various parts of the world. Some of these include; *A. mellea* (Europe, North America, North Asia, Japan and Africa) *A. affinis* (Central America), *A. borealis* (Northern Europe, Russia) *A. cepistipes* (Europe, North America, Japan), *A. gallica* (Europe North America, Japan) *A. leuteobubalina* (Australia), *A. nigritula* (Britain), *A. sinapina* (Canada), *A. nabsona* (Western New Zealand), *A calvenscens* (USA) and *A. ectypa.* Others are, *A socialis, A. novae-zelandiae* (New Zealand, New Guinea, Eastern Australia, South America), *A gallica, A. lutea, A. bulbosa and A heimii*).

Obviously the need for proper identification of African *Armillaria* deserves more attention. It is hoped that with the development of numerous technologically based techniques of identification (Fox, 1990a, 1990b, 1997; Schulze *et. al.* 1997, 1998; Bragaloni *et al.* 1997, Chillali *et al.* 1998) this barrier will soon be broken. Fortunately, more scientists are beginning to show interest in this aspect of research with African *Armillaria* (Abomo – Ndongo *et al.* 1997; 1998; White *et al*, 1998). It may even be possible that what is being regarded as *A mellea* consists of several distinct biological species.

Usually, basidiosomes are rarely formed by *Armillaria*, in the tropics; scarcity of fruiting bodies may be partly responsible for the little information available on species descriptions of *Armillaria* from Africa. The fruiting bodies of African *Armillaria* when formed differ in size and colour compared to those from the temperate regions.

In addition, complete absence of rhizomorphs was reported in most parts of Africa. Hence transmission of infection was by root contact. Rhizomorphs play a major role in the transmission of the disease in temperate regions of the world. These were some of the early indications of differences in several aspects of the biology and probably pathogenicity (Popoola & Fox, 2000) of African *Armillaria*. Similarities were however observed in the microscopic characters of spores. Because of these bottlenecks, records have been arbitrarily attributed to *A. mellea*. But it is now generally accepted that Armillaria root rot found in different parts of the world is in fact a complex of similar diseases caused by distinct *Armillaria* species which differ in their ecology and pathogenicity. A proper identification is a prelude to the development of an appropriate control measure.

Diagnosis, Prevention and Control

Except with physical examination of infected plants, early diagnosis of *Armillaria* root rot can be difficult. Production of fruiting body is erratic, where fruiting bodies are readily formed; this may be a way of getting to now that a plant is infected. However, this appears (if at all) serve as a sign of an established infection. The role of basidiospores in dispersion of the disease is considered negligible as they are hardly formed. Where rhizomorphs are formed, this can also give a clue. Unfortunately, rhizomorphs are rarely formed in the tropical regions except in high altitudes (Rishbeth, 1980).

Attempts have been made (Fox and Hahne, 1988) at developing immunological techniques based on use of polyclonal antiserum and use of enzyme-linked immunosorbent assay (ELISA) for detecting root infection by pathogenic species of *Armillaria*. Although, use of Polymerase Chain Reaction (PCR) method of identification is increasingly becoming widespread, it is likely that most diagnostic methods will have to co-exist. There is still a need for a rapid and definite diagnostic tool for *Armillaria*.

Based on several reports, environmental factors have a role to play in *Armillaria* infections. Thus, like many diseases, *Armillaria* root rot can be controlled by altering the environmental factors which determine the infective activity of the pathogen. Some of these factors are still not clearly understood, they are thought to include water logging, shading, defoliation, humidity, soil types and loss of vigour of host plant due to other disease agents. Some of these factors often interact to predispose a plant to infection. This may be a limitation to complete reliance on the use of environmental management for control and spread of infection. Some African isolates of *Armillaria* will however infect and kill the host plant in the absence of a predisposing factor. (Popoola and Fox, 1989).

Good husbandry, particularly removal and destruction of dead stumps and infected roots have been effective in controlling the menace of *Armillaria* root rot. Control of the pathogen based on the destruction of the pathogen is not as popular as the physical removal of infected root inoculum and avoidance of predisposing factors. It is advisable not to replant on infected sites.

Carbon disulphide and methyl bromide have been used as soil fumigant prior to replanting. Formalin could have been another alternative, but it is now considered to be unsafe. Recently, several new generation chemicals have been tested for their efficacy in controlling *Armillaria*. (Turner and Fox, 1988). The chemicals have shown both eradicant and protectant properties in laboratory tests without being phytotoxic to a variety of plants. Experiments have however shown that different species of *Armillaria* show significant and consistent differences to chemicals. This further confirms the need for a proper understanding of the biology of this pathogen. Prospect for the use of biological control using *Trichoderma* isolates is also being considered (Onsando, 1997). Raziq and Fox (2003; 2004) reported the efficacy of antagonistic activities of selected fungal isolates against *A. mellea*. The search for appropriate biological and chemical control methods is still continuing.

Case Study: *Armillaria* in Nigerian plantations

One of the early documented studies on *Armillaria* in Nigerian forests was that of Fox (1964) undertaken to assess root diseases of rubber plantations in Eastern Nigeria. The visit which was at the instance of Malayan government was repeated in 1970. *Armillaria mellea, Fomes lignosus, Fomes noxious* and *Ganoderma psuedofferreum* were listed as the major root and butt rot pathogens in Nigeria. He observed that root diseases of *Armillaria* were more prominent. In line with the observations of Dade (1927) in Gold Coast and Pichel

(1956) in Congo, Fox (1964) reported that transmission of the disease was by root contact as no rhizomorph were formed. Although, infection manifested on nursery plants, trees in older plantations were more infected Elevation, drainage and pattern of rainfall and humidity enhanced incidence and severity of the disease. A summary of observations of root diseases recorded on rubber plantations in Eastern Nigerian rubber plantation are presented in Tables 1 and 2.

Although, butt and root rot has been diagnosed in Nigeria for a long time, there are no accounts and accurate statistics on the total number of stands lost per tree type per year and the financial implications. Since the report of Momoh (1974) on butt and root rot diseases of teak (*Tectonia grandis*); research into the menace of *Armillaria* in Nigerian forests received very little attention. Perhaps, this was because more attention was being given to establishment of new plantations which concentrated on cultivation of new varieties which came with disease resistance attributes

Consequently, a survey was commenced to assess the status of *Armillaria* root and butt rot in Nigerian forests. During the survey, which covered several ecological zones of the country, notes were also made of other root and butt diseases caused by other pathogens. The study was concluded in 2001.

Table 1: Summary of a sample survey carried out on a Beta type Rubber plantation in Eastern Nigeria (1964)

	Year of planting				
	1957	1958	1959	1960	1961
No. of trees planted	532	429	174	448	400
% vacant*	26.1	36.4	40.2	28.1	30.5
No of points standing	393	273	104	322	278
Armillaria. mellea	15.0	4.0	1.0	0.9	0.4
Fomes lignosus	7.1	35.9	5.8	0.6	1.1
F. noxius	0.8	0.4	0.0	0.0	0.0
Ganoderma pseudoferrum	0.3	0.0	0.0	0.3	0.0
All diseases	23.2	10.3	6.8	1.8	1.5

*includes all standing trees which were dead but not from root disease.
Source: R.A. Fox (unpublished report / per. comm.).

Table 2: Percentage infection by pathogen and age of plants at a Rubber plantation in Eastern Nigeria

Year of planting	*Armillaria. mellea*	*Fomes lignosus*	*Fomes. noxius*	*Ganoderma psuedoferreum*
1957	47.6	13.0	1.8	0.0
1958	17.5	5.0	1.2	0.7
1959	17.5	3.4	1.2	1.2
1960	7.6	10.2	4.1	0.5
1961	10.3	8.9	6.1	0.0
1962	12.1	13.8	2.4	1.4
1963	5.0	11.1	3.3	0.7
1964	0.5	7.0	0.5	0.0

Source: R.A. Fox (1970). Unpublished report.

During the survey, several research institutes particularly CRIN, FRIN, NIFOR and other related establishments were visited. Also, Teak (*Tectonia grandis*), *Gmelina* (*Gmelina arborea*), Eucalyptus (*Eucalyptus citridora*), Oil palm (*Elaies guineensis*), Cocoa (*Threobroma cacao*) and Pine plantations / experimental plots were assessed in addition to Rubber (*Hevea brasilensis*) plantations in the Eastern parts of the country. Special attention was given to the plantations visited by Fox R.A. in 1964 and 1970. This was to enable a comparison of earlier reports.

The survey covered more ecological zones and sampled more plant species. Some of the sampling sites have a particular plant species associated with them. Area J4 in Ogun State has Teak and *Gmelina* dominating. Other sampling sites incude, Olokemeji, Gambari, Akilla, Ajebamidele, Area J5, Sapoba, Nimba, Ikenne, Jemma and private Cocoa farms in Ondo state.Sampling was done on randomly selected plants at a site. Visual and detailed examinations of the root systems and butt region of plants were done. Isolations were also made from infected roots. A summary of the results showing the status of infection on an Eastern Rubber plantation earlier visited is presented in Tables 3, while Table 4 shows infection rate on different plant species assessed.

From the data collected, *Armillaria* root rot still prevails in Nigerian forest plantations, but significantly reduced compared to the observations of Fox (1964). Incidence of occurrence on swampy sites in Eastern Rubber plantations was also greatly reduced.

Table 3: Comparisons of % infection of major pathogens and age of planting on an Eastern Rubber plantation

	A.mellea		*F.lignosus*		*F. noxus*		*G.. psuedoferreum*		No. of blocks sampled*
	Period (year) of invesitgation								
Yr. of planting	1970[1]	1999	1970	1999	1970	1999	1970	1999	
1957	47.6	10.6	13.0	0.90	1.80	1.40	0.0	0.0	8
1958	17.0	15.2	5.0	2.10	1.20	0.90	0.7	0.01	8
1959	17.5	12.5	3.4	1.50	1.2	0.6	0.2	0.04	9
1960	7.6	5.2	10.2	3.2	4.1	1.02	0.5	0.01	12
1961	10.3	8.3	8.9	5.3	6.1	2.01	0	0.01	4
1962	12.1	10.3	13.8	5.2	2.4	0.9	0.4	0.02	4
1963	5.0	2.4	11.1	3.4	3.3	0.8	0.7	0	5
1964	0.5	0.01	7.0	0.5	0.05	0.01	0.10	0	3
1970 and above		1.05		0.02		0.01	0		2,500**

[1] 1970 data provided by R.A. Fox.

* Each block represents ¼ mile run, 53 blocks represents 13¼ miles. Applicable to 1970 data only.

** No. of plants sampled. (1990-1999)

Table 4: Root and butt rot pathogens on plant species from various ecological zones

			Plant type				
Fungi	Rubber	Teak	Cocoa	Oil palm	*Gmelina*	Eucalyptus	Pine
Armillaria spp	3.5	0.5	1.10	0.007	0.05	1.3	1.6
F. lignosus	1.1	2.5	0.43	0.17	0.10	0.95	0.15
F. noxius	1.3	2.3	0.45	0.09	0.45	0.06	.05
G. pseudoferrum	0.01	0.01	0.02	0.04	0.03	0.20	0
Others (*Fusarium* spp. *Pythium* spp. *Rhizoctonia* spp)	1.4	1.5	0.98	0	001	0.05	0

Figures represent % infected plants of the total number of plants sampled

Most of the swamps are gradually drying up perhaps due to several factors which may include global warming and human activities. Since several environmental factors have been implicated as one of the predisposing factors for infection, it may be possible that changing global weather have had some effects on incidence of *Armillaria* root rot in this part of the country. A somewhat similar view was expressed by Balogun and Salami (1995). This has not been the case with some East African countries particularly where cool temperate weather prevails.

Root rot diseases on beta plantations in Eastern rubber plantations was more on older stands than younger plants, as observed by Fox (1964). Wind throw was common on older plants with severe infections as the roots must have been seriously weakened by root pathogens. Often, other saprophytic fungi quickly colonise weak and infected plants. Fruit bodies and rhizomorphs were not found, an indication that transmission was by root contact. This confirms observation of other workers in other parts of Africa.

Conclusions

The result of the survey indicates that *Armillaria* root diseases prevail on plants of economic importance in Nigerian forests. Though negligible compared to earlier reports, one may want to feel that it, could be "written off". However, if proper care is not taken, problems of root rot diseases could be an obstacle to increasing productivity of trees of both local and export importance. The low records should therefore not be taken for granted.

Presently, wood consumption pattern is showing superiority over supply, consequently the Africa Development Bank (ADB) is investing an enormous amount of funds in the agro-forestry sector of the economy of most African countries. To make this investment worthwhile, it is suggested that government of African countries through their various agencies should encourage research into the pathology aspects of agro-forestry

Adequate research and training of Field Assistants is suggested. It may also be necessary to employ competent forest or plant pathologists for the plantations. More trees, indigenous and exotic should be screed for root and butt rot for an effective sustenance of an effective aforestation programme. The long term economic benefits could be enormous.

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