Phytophthora megakarya: A potential threat to the cocoa industry in Ghana

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ABSTRACT

A severe black pod disease of cocoa in Ghana caused by *Phytophthora megakarya* was first reported in 1985, even though there is evidence that the fungus might have existed earlier. Until then, only *Phytophthora palmivora* which causes a less severe black pod disease was known in Ghana. *P. megakarya* has changed the status of black pod disease in Ghana, causing serious crop losses and great concern among farmers. The distribution, disease characteristics and spread of *P. megakarya*, the black pod disease incidence and effect on yield of cocoa in Ghana, are reviewed. Records of cocoa sales and data from on-farm farmer-managed control trials have been presented to illustrate cocoa-yield patterns in *P. palmivora* and *P. megakarya*-affected districts. Problems associated with the control of black pod disease caused by *P. megakarya*, and the measures developed for its management are also discussed. Because black pod disease caused by *P. megakarya* poses a serious threat to cocoa production in Ghana, efforts should be made by all stakeholders to ensure its effective management.

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RÉSUMÉ

OPOKU, I. Y., APPIAH, A. A., AKROFI, A. Y. & OWUSU, G. K. : Phytophthora megakarya *: Une menace potentielle à l' industrie de cacao au Ghana.* Une maladie grave de cosse noire du cacao au Ghana causée par *Phytophthora megakarya* était signalée pour la première fois en 1985, malgré le fait qu'il ait une évidence que le fongus aurait pu être présent avant cette date. Jusque-là, c'est seulement *Phytophthora palmivora*, qui est la cause d'une maladie moins grave de cosse noire, était connue au Ghana. *P. megakarya* a changé la situation de la maladie de cosse noire au Ghana, causant des pertes sévères des cultures et de grande inquiétude pour les cultivateurs. La distribution, les caractéristiques de maladie et propagation de *P. megakarya*, la situation de la maladie de cosse noire et son effet sur le rendement de cacao au Ghana sont passés en revue. Les rapports des ventes de cacao, et les données des essais de contrôle exploité par le cultivateur sur le champ ont été présenté pour illustrer les orientations de rendement de cacao dans les districts affectés par *P. palmivora* et *P. megakarya*. Les problèmes liés au contrôle de la maladie de cosse noire causés par *P. megakarya* et les démarches développées pour son contrôle sont également discutés. Puisque la maladie de cosse noire causée par *P. megakarya* pose une menace serieuse à la production de cacao au Ghana, des efforts doivent être fait par toutes les dépositaires d'enjeux pour assurer son contrôle efficace.

Introduction

Diseases probably constitute the most serious constraints to cocoa production in the world. The five most important diseases of cocoa are black pod, swollen shoot, witches' broom, *Monilia* pod rot, and vascular-streak dieback. Together, they may destroy up to 40 per cent of the world's total crop annually (Thorold, 1975). Of these diseases, only black pod, caused by species of *Phytophthora*, has been recorded in all cocoa-growing countries of the world. The disease, however, seems more important in West Africa than in other cocoa-growing regions. Two main species of *Phytophthora* occur on cocoa in West Africa: *P. palmivora* which causes a less severe black pod disease, and *P. megakarya* which is more virulent and causes a severe black pod disease. In Nigeria, Williams (1977) described black pod disease (probably caused by *P. megakarya*) as the greatest single set-back to economic

production of cocoa and noted that in areas where losses were up to 90 per cent, cocoa cultivation was unprofitable. In Cameroun and Togo, pod losses due to *P. megakarya* can be up to 90 per cent, respectively (Djiekpor *et al.,* 1981; Wood & Lass, 1985).

Until the mid-1980s, the only known black pod disease in Ghana was that caused by *P. palmivora* which resulted in pod losses of 4.9 to 19 per cent (Blencowe & Wharton, 1961; Dakwa, 1984). In 1985, a severe outbreak of black pod disease, which appeared different from that previously known, was reported in the Akomadan area of the Ashanti Region (Dakwa, 1987). Laboratory investigations on diseased cocoa pod samples showed that *P. megakarya* was the causal agent (Dakwa, 1987), and this has subsequently been confirmed (Luterbacher & Akrofi, 1993; Opoku, 1994). This was the first reported occurrence of the species in Ghana, but earlier observations and studies in the Volta Region (Asare-Nyako, 1975; Dakwa, 1975) indicated that the disease might have existed there, perhaps as far back as the early 1970s. *Phytophthora megakarya* had been reported in many other African cocoa-growing countries including Nigeria, Togo, Gabon, Equatorial Guinea, and Cameroun before 1985 when it was first reported in Ghana (Brasier & Griffin, 1979; Djiekpor *et al.,* 1981). *P. megakarya* is, therefore, a serious threat to the cocoa industry in West Africa.

The occurrence of *P. megakarya* in Ghana has changed the status of black pod disease in Ghana. The disease now poses a serious threat to the cocoa industry and has caused great anxiety and concern in many cocoa-farming communities. Pod losses to *P. megakarya* in Ghana are estimated at between 60 and 100 per cent (Dakwa, 1987), and some farmers in the affected areas have had virtually no crop for many seasons. As a result of the disease, farms are being neglected or abandoned (Anonymous, 1995) and some farmers seemingly have little or no enthusiasm in establishing new cocoa farms in the affected areas. In addition, farm caretakers are leaving the affected farms to concentrate on other crops.

Reports from cocoa farmers and extension staff as well as observations in the field during black pod surveys (Opoku, Akrofi & Appiah, 1997) indicate that *P. megakarya* has spread to some important cocoa-growing areas of the Ashanti, Brong Ahafo, and Western Regions, leading to an upsurge of the disease in these areas. The disease is not only causing heavy pod losses, but also serious stem cankers resulting in the death of many cocoa trees (Opoku, Akrofi & Appiah, 1996a).

Unless concerted efforts are made to effectively manage and contain the disease, *P. megakarya* will greatly reduce cocoa production in Ghana.

This paper describes the spread and distribution of *P. megakarya,* and the status of black pod disease in Ghana. It also discusses the measures being taken to manage the disease.

The spread of *P. megakarya* in Ghana

When the black pod disease caused by *P. megakarya* was first reported in the Akomadan area of the Ashanti Region in 1985, it covered an estimated 16,000 ha of land and was apparently spreading at the rate of 3.2 km/year (Dakwa, 1987). By 1994, *P. megakarya* had spread to as far as Essam in the Western Region, a distance of about 176 km from Akomadan. The pathogen has also been identified in four cocoa districts in the Ashanti Region, five in the Brong-Ahafo Region, and three in the Western Region. In the Volta Region, all the cocoa districts are affected, perhaps for much longer periods than elsewhere (Luterbacher & Akrofi, 1993; Opoku *et al.*, 1997). Thus, about 25 per cent of the cocoa districts of Ghana are now affected by *P. megakarya* (Fig. 1). It is, therefore, evident that *P. megakarya* is spreading fast in the country, and that its spread to the two remaining cocoa regions (Eastern and Central) is probably a matter of time. The presence of *P. megakarya* in the Offinso, Tepa, Goaso, Sankore, Essam, and Juabeso Districts (Fig. 1) is a matter of great concern, since these are important cocoa-producing areas with considerable

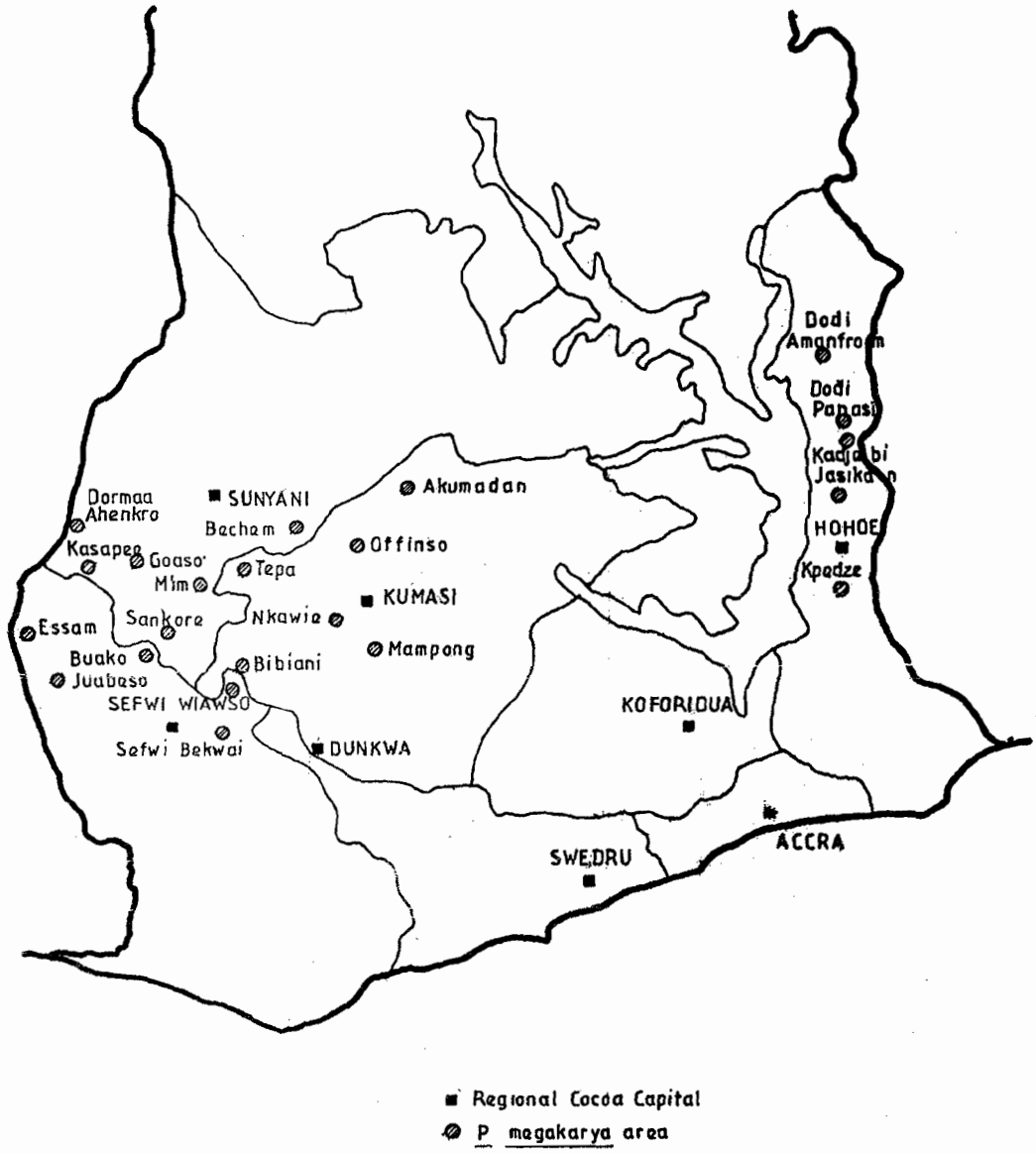

Fig. 1. The distribution of *P. megakarya* in Ghana as shown by limited surveys from 1992 to1998.

contributions to the overall national output.

The rapid spread of *P. megakarya* in Ghana suggests that human or other efficient means of dispersal may be involved. Since soil is the main site of survival as well as source of primary inoculum for *P. megakarya* in the field (Muller, 1980; Brasier, Griffin & Maddison, 1981; Dakwa, 1987), the movement of soil or materials associated with soil always carries the risk of spreading the fungus to new areas. Opoku & Akrofi (1998) consistently isolated *P. megakarya* from non-surface-sterilized root pieces of plantain and

banana suckers and cocoyam corms, indicating that these crops can carry the pathogen probably in contaminated soil adhering to the root surfaces, although the crops themselves may not be alternative hosts. It is, therefore, likely that the movement of planting materials such as cocoa pods, cocoa seedlings, plantain suckers, and cocoyam corms from one farm to another farm or district contributes to the spread of *P. megakarya*. This practice may also be important where farmers do not obtain the recommended planting materials from the Cocoa Seed Gardens, but instead harvest pods from farms where *P. megakarya* is present. The movement of timber trucks through farms and districts may also help to spread the pathogen.

Early possible occurrence of *P. megakarya*

Phytophthora megakarya has probably been in Ghana for many years on other alternative host(s). Turner (1960) reported that an isolate of *Phytophthora* from *Mimusops elengi* (isolated by Dade, 1928) at Aburi in Ghana was distinctly different from what was then known as cocoa or G-isolate. Turner (1960) mentioned that the *Mimusops* isolate produced oospores in mixed culture with the cocoa isolate. Photographs and sporangia dimensions and the nature of pod lesions produced by the G-isolate closely resembled those of the so-called rubber or N-isolate. The G-isolate has now been identified as *P. palmivora* and the N-isolate as *P. megakarya* (Brasier & Griffin, 1979). However, Turner (1960) indicated that isolates collected from cocoa trees adjacent to the infected *Mimusops elengi* after 30 years, were all of the G-type.

Black pod surveys in the 1970s (Dakwa, 1975, 1976) also showed that parts of Volta Region (particularly Dodi Papase and Dodi Amanfrom) consistently had the highest black pod disease incidence. Yields in Volta Region were also much lower than the national average. It is now suspected that the black pod disease in the Volta Region in the 1970s was predominantly the type caused by *P. megakarya*. The Volta Region shares a common boundary with the Republic of Togo where *P. megakarya* was the dominant species (Djiekpor *et al.*, 1981). There is heavy traffic of humans, animals and goods across the borders, and some cocoa farms on either side stretch across the common border. Dakwa (1987) obtained sufficient evidence to suggest that *P. megakarya* probably occurred in the Akomadan area of the Ashanti Region as far back as 1980, but remained unreported until 1985 when many farms were affected.

Apparently, before *P. megakarya* was reported in Ghana, some harm had already been done. For instance, between 1970 and 1987, farmers continued to receive planting materials from Cocoa Seed Gardens in the apparently *P. megakarya*-infected areas of Akaa in the Volta Region, Akomadan in the Ashanti Region, and Bechem in the Brong-Ahafo Region. Although different management practices are required for black pod disease caused by *P. palmivora* and *P. megakarya*, until 1986, all control practices were directed towards *P. palmivora* alone. Probably, the heavy pod losses incurred in the Volta Region in the 1970s (Dakwa, 1976) and the Akomadan area between 1980 and 1986 (Dakwa, 1987) were because *P. megakarya* had not been recognized and, therefore, the appropriate measures were not applied. By the time *P. megakarya* was identified, many cocoa farms had either been abandoned (as in the Volta Region) or neglected (as in the Akomadan area) (Anonymous, 1995).

Characteristics of black pod disease of cocoa

Black pod disease caused by *P. megakarya* has been described in some farming communities in Ghana as a strange disease. The anxieties and concerns of farmers are understandable, given the fact that the manifestations of *P. megakarya* infections are, in many ways, different from those of the previously known *P. palmivora* infections.

Virulence of P. megakarya

P. megakarya is more virulent, more aggressive and by far a better competitor on cocoa than *P. palmivora*. Wherever the two species are known

to co-exist, *P. megakarya* is always the predominant species (Brasier *et al.*, 1981; Djiekpor *et al.*, 1981; Luterbacher & Akrofi, 1993; Luterbacher, 1994; Opoku *et al.*, 1997).

The main inocula of *P. palmivora* and *P. megakarya* are sporangia and zoospores. However, *P. megakarya* does not only produce sporangia faster and in much greater quantities (4-6 times more) than *P. palmivora*, but it also discharges its zoospore from the sporangia sooner (about 10 min earlier) than *P. palmivora* (Brasier *et al.*, 1981; Luterbacher, 1994; Opoku, 1994). Thus, as a result of the abundance of infective propagules, *P. megakarya* can infect more pods within a very short time than *P. palmivora.* Multiple pod infections due to *P. megakarya* are also very common. A single pod in a farm where *P. megakarya* is present, can carry as many as 20 or more lesions of different sizes (Opoku *et al.*, 1997). These individual lesions soon coalesce, covering and destroying the pod and beans within a few days.

In *P. megakarya*-infected areas, primary infections are usually not confined to only a few pods (as with *P. palmivora*), but to many pods at the same time and the dispersal mechanism is also very efficient (Dakwa, 1987). Pod to pod infection occurs at such a fast rate that under very humid conditions, an entire crop could be infected within 2 weeks after the first detection of primary infections.

Pod losses caused by P. megakarya

From recent black pod surveys (Luterbacher & Akrofi, 1993; Opoku *et al.*, 1997) and interviews with cocoa farmers, it is now obvious that black pod disease is the most serious problem facing farmers in the *P. megakarya*-affected areas. Pod losses are extremely high, ranging from 60 to 80 per cent on farms in which the disease first appeared, to almost 100 per cent in old-affected farms (Dakwa, 1987). On old-affected farms, infections are confined to either cherelles or immature pods which do not get the opportunity to mature (Dakwa, 1987). In contrast, *P. palmivora* pod losses are estimated at between 4.9 and 19 per cent (Blencowe & Wharton, 1961; Dakwa, 1984). During the black pod conducive period of September to October, it is very common in *P. megakarya*-infected areas to find trees with entire crop of pods totally blackened by infection.

Data obtained from on-farm farmer-managed fungicide trials (Akrofi *et al.*, 1997) clearly indicate the severity of black pod disease caused by *P. megakarya* (Table 1). The results confirmed earlier reports that black pod disease incidence was high wherever *P. megakarya* occurred (Dakwa 1987; Opoku *et al.*, 1997). The mean disease incidence recorded in the seven districts was 60.1 per cent (range: 20.5 to 95.7 %) and Essam, one of the leading cocoa-producing districts in Ghana, had the highest disease incidence of 76.5 per cent. Cocoa production in the Essam district is declining (Table 2), apparently because of black pod disease.

TABLE 1

Black Pod Disease Incidence on Unsprayed Plots of Farmer-Managed Fungicide Trials in Five P. megakarya*-affected Districts of Ghana*

District	*% disease incidence**					*District mean*
	Farmers					
	A	*B*	*C*	*D*	*E*	
Goaso	47.7	75.0	76.4	47.7	58.7	61.1
Bechem	45.5	87.7	20.5	27.6	77.3	51.7
Offinso	95.7	85.9	29.8	65.5	28.0	61.0
Essam	86.2	87.8	61.9	56.8	89.8	76.5
Kpeve	-	35.1	55.5	78.9	64.4	58.5

*= Pods with black pod disease as a percentage of total pods.

- = Farm identified to be infected with *P. palmivora* only; value not included.

Source: Annual Report of the Cocoa Research Institute of Ghana, 1995/96.

Phytophthora megakarya *canker*

In Ghana, *P. megakarya* and *P. palmivora* form stem cankers very readily (Opoku *et al.*, 1996a). However, unlike *P. palmivora* cankers which are usually distributed normally on the tree trunk, *P. megakarya* cankers tend to be concentrated on the lower part of the stem close to the ground; cankers do, however, occur on all parts of the tree.

The canker lesions often extend below the ground level into the roots (Opoku *et al.*, 1996a). At such locations, treatment with chemicals becomes very difficult. Multiple cankers with large lesions commonly occur on trees infected with *P. megakarya*. The lesions can girdle the stem and this usually results in the death of a branch or a whole tree.

TABLE 2

Cocoa Production in Nine Districts in Ghana where P. megakarya *is Prevalent*

District	*Year/tonne*				
	1988/89	*1989/90*	*1990/91*	*1991/92*	*1992/93*
Dobidi-Dodo	157	151	473	322	416
Sankore	7279	6977	7209	5632	5924
Goaso	5289	4746	4243	3760	4470
Bechem	1033	742	500	502	449
Offinso	6395	5551	4380	5306	4347
Nkawie	2893	3372	2054	2085	2365
Tepa	2134	1637	770	1294	1141
Essam	8905	5830	7870	7364	6633
Juabeso	7296	3106	3282	3028	3599
Annual total	41381	32112	30781	29293	29344
Annual mean	4597.9	3568.0	3420.1	3254.8	3260.4

Source: Produce Buying Company Limited (Ghana Cocoa Board), Accra.

Control of P. megakarya *and associated problems*

Phytophthora megakarya and *P. palmivora* are mainly soil-borne pathogens and their control is therefore difficult. Okaisabor (1974) isolated *P. palmivora* from soil throughout the year, and there is evidence that *P. megakarya* has a self-sustaining reservoir in cocoa plantation soils (Gregory & Maddison, 1981). Soils contaminated with *P. megakarya* or *P. palmivora* are easily and readily carried by rodents, ants, and other invertebrates (Evans, 1971) from the soil up the tree unto healthy pods. Ant tents on the tree and cocoa pods may not only contain inocula of *P. megakarya* and/or *P. palmivora*, but may also interfere with the placement of fungicides.

For many years, Ghana cocoa farmers have produced cocoa with virtually no fungicides. This was because the predominant black pod disease was that caused by *P. palmivora* and could be managed by cultural practices such as regular weeding, pruning, shade reduction, and frequent harvesting (Wharton, 1962). This situation completely changed with *P. megakarya* infections in 1985. With black pod disease due to *P. megakarya*, cultural practices alone are inadequate for disease control and they have to be supplemented with fungicide application (Opoku, Akrofi & Appiah, 1995). Unfortunately, for effective chemical control of *P. megakarya*, spraying has to be at short intervals.

Spraying of copper or copper/metalaxyl mixtures at 5- or 6-week intervals failed to control *P. megakarya* (Opoku *et al.*, 1995). It has also been reported that *P. megakarya* is more tolerant to copper than *P. palmivora* (Filani & Griffin, 1977). At the current recommendation of 3- or 4-weekly applications, farmers are expected to spray between five and eight times in a season, depending on the pattern of rainfall. Unfortunately, the black pod season (May to October) also coincides with other additional farming activities some of which are unrelated to cocoa. Hence, many farmers are unable to follow the chemical control programme.

Chemical control is also expensive. With the high cost of inputs, especially fungicides and spraying machines, chemical control is increasingly becoming unattractive to many peasant farmers. At eight applications *per* season, the cost of fungicide treatment of a hectare of cocoa farm in Ghana is estimated at ¢780,000.00 (US $130). Many farmers are apparently unable to afford this, and the consequences are that little or no fungicide is applied, resulting in poor disease control. The contamination of the environment as a result of repeated application of fungicides is also a source of concern, but this is apparently not serious in other countries (e.g. Cameroon) where chemical control of black pod disease has

been practised for many years.

P. megakarya and yield decline in cocoa

Black pod disease is clearly one of the most important factors causing yield decline in *P. megakarya*-endemic areas. It is of major importance to farmers, although the effects of other factors such as pests, swollen shoot disease, loss of soil fertility, and unfavourable climatic conditions cannot be ignored. Field observations, interviews with farmers and extension staff as well as examination of current production trends in *P. megakarya*-endemic areas indicate that the disease has had devastating effects on yield, and that some farmers have virtually had no crop for many seasons (Opoku, Akrofi & Appiah, 1996b).

TABLE 3

Cocoa Production in Nine Districts in Ghana where only P. palmivora *occurs*

District	*Year/tonnes*				
	1988/89	*1989/90*	*1990/91*	*1991/92*	*1992/93*
Juaso	2996	2970	2964	2404	3162
Enchi	5807	7347	9144	7867	12868
Samreboi	3269	2903	3577	2880	5043
Asankrangwa	4364	3979	4403	3265	4942
Assin Fosu	5380	5622	5749	4292	6685
Dunkwa	8107	8490	9297	5497	9243
Kade	3597	3149	3051	2463	3422
Asamankese	2257	1960	1775	1294	3428
Nkawkaw	2264	2307	2118	2068	2412
Annual total	38041	38727	42078	32030	51205
Annual mean	4226.8	4303.0	4675.3	3558.9	5689.4

Source: Produce Buying Company Limited (Ghana Cocoa Board), Accra.

Tables 2 and 3 show the production figures from the largest cocoa buyer, the Produce Buying Company Limited (PBC), between the 1988/89 and 1992/93 cocoa seasons in nine *P. megakarya* and nine *P. palmivora*-affected cocoa districts, respectively. In general, cocoa production in the *P. megakarya*-affected districts declined over the 5-year period, although there were fluctuations in some districts. The overall production in the nine districts fell from 41,381 to 29,344 tonnes, representing a drop of 29.1 per cent (Table 2). On the contrary, production in the *P. palmivora* districts generally increased during the period, rising from 38,041 tonnes in 1988/89 to 51,205 tonnes in 1992/93, representing a rise of 34.6 per cent (Table 3).

Similar trends were observed when yields of 40 farmers in each of four *P. megakarya* and four *P. palmivora*-affected districts from 1992/93 to 1995/96 were examined (Tables 4 and 5). In the *P. megakarya*-affected area, a total of 256.7 tonnes of cocoa was recorded in 1992/93, but the yield declined from season to season and in 1995/96, only 172.7 tonnes were recorded, representing a substantial drop of 32.7 per cent. On the other hand, production in the *P. palmivora*-affected districts in the same period increased substantially from 362.1 tonnes in 1992/93 to 567.5 tonnes in 1995/96, a rise of 56.7 per cent.

Effective ways to manage black pod disease caused by *P. megakarya*

As complete eradication of *Phytophthora* from cocoa farms is not feasible, some losses due to black pod disease are inevitable. Hence, measures that can sustain economic production of cocoa should be pursued.

TABLE 4

Cocoa Produced by 40 Farmers in Four Districts in Ghana where P. megakarya *is Predominant*

District	*Year and tonnage*			
	1992/93	*1993/94*	*1994/95*	*1995/96*
Tepa	52.5*	46.1	35.0	37.9
Offinso	112.2	95.9	96.1	57.3
Bechem	31.9	32.4	27.8	33.1
Nkawie	60.1	63.8	45.8	44.4
Annual total	256.7	238.2	204.7	172.7
Annual mean	64.2	59.6	51.2	43.2

*Each figure is the total production of 40 farmers.
Source: Sales recorded in farmers' passbooks by Produce Buying Company Limited.

TABLE 5

Cocoa Produced by 40 Farmers in Four Districts in Ghana where P. palmivora *is Predominant*

District	*Year and tonnage*			
	1992/93	*1993/94*	*1994/95*	*1995/96*
Juaso	64.9*	68.3	72.0	72.1
Oda	69.0	131.8	124.4	142.2
Nkawkaw	45.8	50.6	60.1	63.8
Asamankese	182.4	219.8	304.8	289.4
Annual total	362.1	470.5	561.3	567.5
Annual mean	90.5	117.6	140.3	141.9

*Each figure is the total production of 40 farmers.
Source: Sales recorded in farmers' passbooks by Produce Buying Company Limited.

The effective management of black pod disease caused by *P. megakarya* requires application of many important factors. These include extensive farmer education, use of less susceptible cocoa cultivars, cultural and chemical control strategies, adequate knowledge of techniques of fungicide application, and the development of novel approaches for control.

Farmer education

In view of the severity of *P. megakarya*-mediated black pod during the disease-conducive period (July - October), some farmers in Ghana believe that it is a strange disease caused by evil forces or the effects of the Volta Lake (Opoku & Owusu, 1995). These erroneous beliefs oblige farmers to adopt wrong attitudes towards its control. Therefore, for any disease management strategy to succeed, there is a need for vigorous farmer education to correct these beliefs. Programmes such as rallies, demonstrations, open days, and workshops should concentrate on explaining the ecological, climatic, and human factors that favour disease build-up. Farmers and extension officers need to clearly understand the epiphytotics of the disease. The current geographic distribution of *P. megakarya* and measures to limit spread to disease-free areas, and effective combination of methods of control all need to be clearly explained to farmers.

Farmer educational programmes have been regularly implemented in Ghana. In particular, special rallies dubbed *"Ye wo afuo yie"* (improve your farm) at which farmers are taught good farm maintenance with special emphasis on diseases and pests, have been held almost every year since 1998. On-farm trials and demonstrations on farmers' fields on the control of black pod disease have been done in all the affected regions since 1991. Moreover, extension units each covering 300 farmers have been established and, since 1994, monthly educational meetings have been held between farmers and trained extension staff at district and unit levels. Thus, as a result of these programmes, many farmers in *P. megakarya*-affected areas are now aware of the disease and the associated destruction if uncontrolled. Such programmes must be sustained.

The habit among Ghanaian farmers of picking pods from one farm to the other for planting could contribute to the spread of *P. megakarya.* It is, therefore, important for farmers to avoid collecting apparently healthy-looking pods from one locality to another, since such pods may be carrying latent infections in the peduncle and pod husk, or may be contaminated with infective soil. The supply of hybrid pods (planting material) to farmers from three seed gardens located in *P. megakarya*-endemic areas has been banned since 1992, a measure instituted to prevent spread of disease.

Cultural and chemical control

Cultural control is the least expensive of all the available control measures and can be undertaken with little financial resources. The growth and development of *P. palmivora* and *P. megakarya* depend on moist and humid or damp conditions. The ability of the fungi to infect and destroy is hindered by improved aeration. Good cultural practices should, therefore, aim at reducing humidity and increasing aeration through judicious reduction of shade on farms, regular weeding, removal of chupons, planting at recommended spacing or thinning out to recommended spacing, and draining stagnant

waters on the farm.

Other cultural practices such as regular harvesting (at least once a month) and removal of all diseased and mummified pods during or in between harvests are very useful management practices. It is important at each harvest, to separate diseased pods from healthy ones, and diseased pods must be opened immediately to salvage beans not yet attacked by the fungus and prevent further destruction. Diseased pods must be burnt and buried or heaped at one place and sprayed with fungicide. Cultural practices alone have, over the years, adequately controlled black pod disease caused by *P. palmivora* in Ghana (Blencowe & Wharton, 1961; Dade, 1927).

For the control of *P. megakarya,* however, cultural practices have to be supplemented with chemical control strategies. Currently, black pod disease is controlled chemically by spraying healthy pods with fungicides by using pneumatic sprayers. This stops germination of fungal spores and growth of germ tubes and mycelia. The current recommended fungicides in Ghana for the control of black pod disease are Kocide 101 (77 % cupric hydroxide), Cacaobre Sandoz (56 % cuprous oxide), Copper Nordox 50 (50 % cuprous oxide), Copper Nordox 75 (75 % cuprous oxide), Champion (77 % cupric hydroxide), and Ridomil 72 plus (12 % metalaxyl and 60 % cuprous oxide). Dosage of fungicides, timing of initial application, frequency and target of application, are all crucial factors to be considered for successful control.

Time of fungicide application. The genus *Phytophthora* thrives in moist environment and is inactive during the dry season. It is, therefore, necessary to spray only during the wet (rainy) season. The best time to start spraying is at the beginning of the rainy season when trees are bearing pods (cherelles to mature green pods) and a few pods with disease symptoms are seen on the farm. In *P. megakarya*-infected areas, spraying must begin when even a single infected pod is seen. It is useless to apply fungicides just before the rain, and the application must be repeated when it rains within 3 h of application. Generally, fungicide application begins in May and continues until the end of October, although this may vary from one locality to another and from year to year.

Frequency of spraying. Once spraying has started, it is important to continue spraying without a break, particularly in *P. megakarya*-infected areas, until the rains are over. The current recommendation is to spray at 3-week intervals, but with Copper Nordox 75 and Ridomil 72 plus, spraying may be at 4-week intervals. It is essential to spray pods regularly for the following reasons:

1. Pods enlarge as they grow and the new growth is unprotected by the fungicide.
2. After spraying, some of the fungicide coating on the pod may be washed off by rain and must be replaced.
3. New pods are always being produced in between sprays and these need protection from black pod infection.

All stages of the pod's development (from cherelle to maturity) are susceptible to the disease and must be protected until it is harvested.

Efficacy of control. It has been observed that in some cases, the control of black pod disease with fungicides is ineffective due to one or more of the following: (1) the use of lower than optimal fungicide dose, (2) spraying onto non-target areas such as leaves and stems rather than the pod, (3) not taking enough care to cover the entire surface of the pod, (4) the use of expired fungicides, (5) the use of unsuitable fungicides, and (6) the use of inappropriate sprayer and nozzle. In Ghana, the old age of most cocoa farmers and the many absentee farmers compel them to rely on hired labour which is usually inefficient in the careful application of fungicide to control black pod disease.

Black pod resistant genotypes

The types of planting material used in establishing new cocoa farms are of major importance in the overall effort to effectively manage black pod disease caused by *P.*

megakarya. No cocoa plant genotype has so far been found with immunity to black pod disease caused by either *P. palmivora* or *P. megakarya* (van der Vossen, 1997), but varietal differences occur and this had been shown in recent studies in Ghana (Abdul-Karimu *et al.*, in press). Since *P. megakarya* is indigenous to West Africa (Griffin, 1977), the search for resistant materials should be concentrated in the sub-region, with collection of additional materials from elsewhere to broaden the genetic base. The use of resistant or tolerant materials would require little additional inputs from farmers to combat the black pod disease.

Novel disease control approaches

The development of novel approaches to manage black pod disease are imperative, considering the problems associated with the current control measures. In Ghana, studies are in progress on the injection of phosphorous acid, a systemic fungicide, for the control of *P. megakarya* and the results so far seem promising (Opoku *et al.*, 1998). The method was first developed in Australia and has been successfully applied on a limited scale in Papua New Guinea to control *P. palmivora*-mediated black pod disease and stem canker. There is also a great potential for the biological control of black pod disease, and research into biocontrol agents need to be intensified.

The use of natural enemies against *P. palmivora* has been shown *in vitro* by several workers including Attafuah (1966), Figuerdo & Medeiros (1977), Frais & Garcia (1981), Odigie & Ikotum (1982), Odamtten & Clerk (1984), McGregor & Moxon (1985), and Bastos, Neill & Horgan (1986). Recently, *Pseudomonas flourescence* isolated from the surface of a healthy cocoa pod was reported to be antagonistic to *P. palmivora in-vitro* and in the field, and was more effective than copper oxide and chlorothalonil (Galindo, 1992). The effectiveness of these bicontrol agents against *P. megakarya* needs to be investigated, and proposals for such studies in Ghana are being considered.

Conclusion

Despite farmer education, demonstration of control on farmers' fields and the severe losses, black pod disease due to *P. megakarya* is not being controlled on many farms. The tradition of cocoa cultivation in Ghana is that farmers do the bare minimum in farm maintenance. Most farmers weed their farms once a year only in July-September largely to facilitate harvesting. Sanitation pruning, shade reduction, removal of diseased pods, and other operations which will reduce black pod disease are usually not carried out.

The adoption of the method of chemical control to supplement cultural practices has been slow. Socio-economic factors such as cultural beliefs, cost of fungicide treatment, availability of fungicides at the right time, availability of water, absentee farmers, and the old age of many cocoa farmers make black pod disease control a difficult task.

Black pod disease caused by *P. megakarya*, a more virulent species than previously known, poses a serious threat to cocoa production in Ghana, and all efforts should be made to ensure its effective management. The use of integrated control to approach this problem should be considered seriously if the crop is to continue as a major foreign exchange earner for Ghana.

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