Available online at www.sciencedirect.com
SCIENCE DIRECT®
Crop Protection 22 (2003) 469–477
Crop Protection
www.elsevier.com/locate/cropro

Management of *Phytophthora* pod rot disease on cocoa farms in Ghana

A.Y. Akrofi[a], A.A. Appiah[b,*], I.Y. Opoku[a]

[a] *Cocoa Research Institute of Ghana, P.O. Box 8, New Tafo, Akim, Ghana*
[b] *Department of Molecular and Cell Biology, Institute of Medical Sciences, Foresterhill, University of Aberdeen, Aberdeen AB25 2ZD, UK*

Received 21 June 2002; received in revised form 16 September 2002; accepted 16 September 2002

Abstract

From 1991 to 1997, field observations on trials involving the use of metalaxyl and copper-based fungicides were made on farmers' farms in four *Phytophthora megakarya* affected cocoa growing regions of Ghana to control *Phytophthora* pod rot disease. Data on farm management practices, cocoa and shade tree types and densities, plot sizes, yield, land tenure and labour arrangements for farm operations, disease incidence and profitability of disease control were collected. Lower disease incidence and higher yields were recorded on fungicide-treated plots than on the untreated plots. The profitability of fungicide application depended on the level of farm management, nature of land tenure and labour arrangements for farm operations. The challenges involved in conducting trials with active participation by farmers are discussed. The involvement of farmers in the development of disease control programmes is crucial for subsequent adoption of the technology.

Keywords: *Phytophthora* pod rot; Cultural practices; Farmer participation; Profitability

1. Introduction

Until 1985, *Phytophthora palmivora* was the only known causal agent for *Phytophthora* pod rot (black pod) disease in Ghana. The appearance of *Phytophthora megakarya* in 1985 in Ghana added a new dimension to the disease complex of cocoa in the country. *Phytophthora* disease incidence and crop losses vary from one locality and farm to another (Akrofi et al., 1997) and also fluctuate with the seasons (Dakwa, 1973). Blencowe and Wharton (1961) reported annual losses of 19% in *P. palmivora* areas while Dakwa (1987) reported 60–100% losses in *P. megakarya* areas. In the Akomadan area, where *P. megakarya* infection has been prevalent since 1985, most of the farmers have abandoned cocoa cultivation altogether for food and vegetable crop production.

Timely application of strategic integrated control measures is imperative for efficient disease management. In Ghana, the integration of cultural and chemical methods has been effective against *P. megakarya* while cultural practices alone, including judicious shade management, pruning, removal of basal chupons, mistletoes and frequent harvesting, can be sufficient to control *P. palmivora* (Asare-Nyako, 1974; Akrofi et al., 1997). Cultural practices are not only essential for increasing yield, but also provide the right environment for the efficient performance of recommended fungicides (Akrofi et al., 1997). Frequent harvesting, for instance, saves partly infected mature pods and reduces sources of sporangial inoculum while shade management, opening up the canopy and reducing basal chupons, enhances air circulation in the cocoa farm, thereby reducing disease incidence (Lass, 1985). The recommendation of 3-weekly fungicide spraying in Ghana (Hislop and Park, 1960) means that at least six applications are required in one black pod season (May–October). This rather high frequency of spraying, coupled with the ever-increasing cost of inputs (labour and fungicides) and the lack of knowledge in techniques for effective spraying, make the adoption of chemical control very low. Four-weekly spraying of either metalaxyl & copper-1-oxide (Ridomil 72 plus) or cuprous oxide (Nordox 75) combined with cultural practices had been found effective against *Phytophthora megakarya* in researcher-managed trials (Akrofi and Appiah, 1995). This spraying regime reduces the number of sprays per season to five and saves cost.

*Corresponding author.

0261-2194/03/$ - see front matter
PII: S0261-2194(02)00193-X

One factor that influences cocoa production (particularly access to land and adoption of innovations) is the tenure system that operates in a particular cultural setting (Brown and Annor-Frimpong, 1994). Since people of distinct cultural characteristics inhabit the cocoa regions, their inheritance systems differ. For instance, the Akans of Bechem area in the Brong Ahafo Region inherit matrimonially while the Ewes of Hohoe patrilineally. Tenure systems affect production through the arrangement between the farmer and the landowner on how much control either of them has over the land (Hill, 1962; Brown and Annor-Frimpong, 1994). In Ghanaian cocoa culture, the two main tenure systems that operate are farmer owned and share cropping. In the former, the farmer owns the farm and is responsible for all operations and takes all the proceeds while in the sharecropping, tenant farmers enter into an agreement (mostly oral) to run the farm on behalf of its owners and in turn share the output. Sharecropping may be either on the basis of "abunu" or "abusa". In "abunu" one party (the tenant farmer) crops the land and takes half of the proceeds while the other half goes to the land owner while in the "abusa", the tenant farmer responsible for farm operations takes one-third of the proceeds and the other two-thirds goes to the land owner.

Related to the land tenure system is the labour arrangement in cocoa production in Ghana. Three categories of labour are identified, namely family, hired and caretaker. Family labour is scanty and hired labour, though generally available, is expensive and difficult to come by, particularly, in areas where farmers of other crops are paid higher wages than cocoa farmers. Caretakers are thus frequently employed for specific farm operations under various labour arrangements.

This paper reports on observations on trials conducted on farmers' farms in selected cocoa districts to demonstrate the effectiveness of recommended fungicides for the control of *Phytophthora* pod rot disease in Ghana. The rationale was to involve farmers in the technology development process. The paper also discusses the profitability of disease control in relation to farm management practices, cocoa and shade tree types and densities, plot sizes, yield, land tenure and labour arrangement for farm operations. The challenges that arose when conducting these trials are also highlighted.

2. Materials and methods

From June 1991 to November 1995, observations were made on trials carried out on 12 farms in the Hohoe district of the Volta Region and on 10 farms in the Bechem district of the Brong Ahafo Region. The observations were extended from 1995 to 1997 to cover five farms in each of the Offinso, Tepa and Nkawie/Kunso (Ashanti Region), Goaso and Bechem (Brong Ahafo Region), Kpeve (Volta Region) and Essam (Western Region) districts (Fig. 1).

Initial meetings to discuss trial objectives and protocols were held at the village level between researchers,

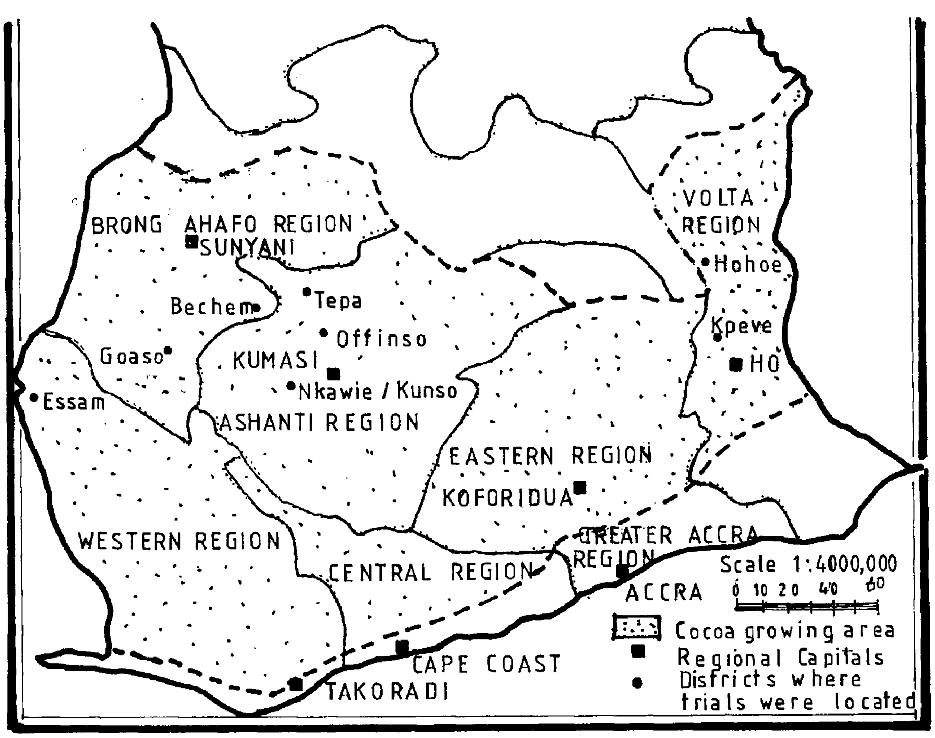

Fig. 1. Map of Ghana showing locations of on-farm trials in cocoa growing regions. 1991–97.

extension personnel and farmers. Farms were then selected after the farmers had agreed to split their farms or portions of it into two plots. One part was sprayed with either (12% metalaxyl and 60% copper-1-oxide (Ridomil 72 plus) Ceiba Geigy Ltd., Basle, Switzerland) or (85% cuprous oxide, Nordox 75, Nordox Industrier, Oslo, Norway) and the other was left unsprayed to serve as control. The choice of fungicide sprayed on each farm was at the discretion of the farmer and the plot sprayed was selected at random. Spraying was done at 4-weekly intervals by the farmers or caretakers at the rate of 50 and 100 g in 15 l of water of Ridomil 72 plus and Nordox 75, respectively, with Cooper Pegler Compression sprayers, fitted with extension lances and cone nozzles. Only pods and cherrelles within reach of sprayer (3.0 m above ground) were sprayed. At monthly intervals, visits were made by researchers to coincide with the spraying of fungicides to facilitate monitoring of the efficiency of spraying, to record other biophysical data and cultural practices done within the month. A farm was recorded as well sprayed when all pods and cherrelles within reach of sprayer were covered with fungicide spray. Extension personnel living in the farming communities also recorded the frequency at which cultural practices were carried out.

The farmers and their caretakers were trained in effective spraying of fungicides at the beginning of the trials. The area of plot on each farm was assessed; varieties and the age of cocoa, the number of cocoa and shade trees on each plot, types and architecture (height, canopy thickness and spread) of shade trees and labour arrangement for farm operations were recorded at the beginning of the study. However, because most cocoa in Ghana is planted at stake and at random, without regard to the recommended spatial arrangements and under unevenly distributed natural shade trees, the number of cocoa and shade trees varied between plots and on farms.

Harvested pods were categorized into healthy and diseased and the data were pooled at the end of the trial. Disease incidence was calculated as the ratio of infected pods to total pods harvested and expressed in percentage. Owing to the variations in plot sizes, yields were related to the tree population per plot. Initial assessment showed that approximately 28 pods gave 1 kg dry weight of cocoa beans and this value was used to compute the dry weight from the pod count.

Socio-economic data (labour cost for spraying, number and cost of fungicides used and revenue from dry cocoa beans) were collected and used to calculate the profitability of fungicide application for each farm. Profitability was calculated as the ratio of the returns accruing from fungicide application to the cost incurred in spraying. A value of 2 or more was considered profitable, between 1 and 2 as break even and less than 1 as a loss. Partial budget analyses were used to calculate the costs of the fungicide component. Meetings were held between researchers, extension personnel and farmers at the end of each season to discuss the success or failure of the treatments.

3. Results

The number of farmers who carried out the various cultural practices in the Hohoe and Bechem districts is indicated in Table 1. None of the 22 farmers carried out shade adjustment, neither did they remove mistletoes and infected pods in between harvests, nor dispose of husks from the cocoa farms. The husks were left under the cocoa trees.

The 4-yr period data (1991–1995) on plot size, cocoa plant density, number of shade trees, mean yield of dry cocoa beans and profitability over the trial period from Hohoe and Bechem districts are presented in Table 2. The variations in plant density, mean yield of dry beans, disease incidence and profitability observed in the 1995–1997 trials in the Ashanti, Brong Ahafo, Volta and Western Regions was similar to that of the trials in the Hohoe and Bechem districts. The mean plant density and yield per hectare, percent disease incidence and profitability were 1257.8 trees, 282.06 kg, 39.32% and 3.66, respectively (Table 3). The mean disease incidence recorded in the Essam district (77%) was significantly ($P<0.01$) higher on the treated plots than the untreated (46%) and the mean yield from treated plots was 42.6% ($P<0.05$) greater than that from the untreated control. The mean disease incidence on the untreated plots in Kpeve district was 50.10% as against 23.60% on the treated plots whilst the mean yield from the treated plots was 12.33% greater than that from the untreated control (Table 3).

Table 1
Adoption of recommended cultural practices in the Hohoe and Bechem Districts, 1991/92–1994/95

Cultural activity	Number of farmers[a]		
	Hohoe District	Bechem District	Total[b]
1. Weeding (once/yr)	4	1	5 (22.7)
2. Weeding (twice/yr)	7	9	16 (72.7)
3. Weeding (thrice/yr)	1	0	1 (4.5)
4. Pruning	3	7	10 (45.5)
5. Removal of basal chupons	2	4	6 (27.3)
6. Shade manipulation	0	0	0 (0.0)
7. Removal of mistletoes	0	0	0 (0.0)
8. Removal of infected pods (between harvests)	0	0	0 (0.0)
9. Disposal of husks	0	0	0 (0.0)

[a] Numbers indicated are out of a total of 12 in the Hohoe and 10 in the Bechem District.

[b] Figures in parenthesis are percentages.

Table 2
Plot characteristics, disease incidence and profitability of *Phytophthora* pod rot control on farmers' farms between 1991/92 and 1994/95

Farmer	Treatment	Hohoe District (Volta Region)						Farmer	Bechem District (Brong Ahafo Region)					
		Area (ha)	Plot characteristics per hectare			Disease incidence (%)	Profitability		Area (ha)	Plot characteristics per hectare			Disease incidence (%)	Profitability
			Cocoa trees	Shade trees	Mean yield (kg)					Cocoa trees	Shade trees	Mean yield (kg)		
A	Treated	0.40	1220	38	368.6	15.27	3.1	A	0.20	1030	20	328.7	18.99	0.7
	Untreated	0.28	1584	28	201.3	32.37			0.12	1411	12	404.9	34.93	
B	Treated	0.24	2525	31	487.2	33.07	6.8	B	0.16	1188	12	424.1	20.48	15.6
	Untreated	0.24	2228	29	191.4	58.04			0.20	1455	15	195.5	28.29	
C	Treated	0.40	1220	36	206.2	22.51	4.9	C	0.12	1477	15	283.2	51.93	1.6
	Untreated	0.28	1213	16	100.4	46.29			0.12	1031	11	198.9	71.26	
D	Treated	0.24	941	103	253.4	18.49	4.5	D	0.28	1160	77	341.1	13.69	0.6
	Untreated	0.20	1005	59	186.4	29.41			0.20	1936	53	323.2	41.44	
E	Treated	0.53	1280	67	428.0	27.55	6.1	E	0.36	998	25	610.1	16.47	19.5
	Untreated	0.44	1593	92	388.5	54.29			0.28	1326	19	515.0	25.13	
F	Treated	0.44	1537	54	378.4	40.07	4.5	F	0.48	592	55	101.5	40.84	15.3
	Untreated	0.57	1298	88	226.5	64.76			0.36	1042	37	49.2	59.52	
G	Treated	0.57	854	41	51.0	34.28	0.8	G	0.36	1757	56	371.3	6.46	5.2
	Untreated	0.36	1579	66	41.7	55.53			0.40	1054	107	196.2	13.61	
H	Treated	0.32	795	20	44.6	7.41	0.7	H	0.36	858	27	341.5	33.89	3.6
	Untreated	0.36	710	14	18.6	18.07			0.40	1050	30	150.8	38.13	
I	Treated	0.16	1547	6	199.3	38.69	2.7	I	0.28	941	21	299.6	23.69	13.5
	Untreated	0.24	941	11	40.1	55.15			0.20	1411	23	198.6	38.13	
J	Treated	0.16	672	10	123.3	10.75	1.1	J	0.12	701	5	270.5	51.63	5.9
	Untreated	0.12	708	16	76.0	53.10			0.12	800	13	77.8	72.73	
K	Treated	0.24	1295	16	370.6	26.08	4.6		—	—	—	—	—	—
	Untreated	0.24	1188	19	91.8	65.33			—	—	—	—	—	
L	Treated	0.40	710	49	81.2	16.78	2.8		—	—	—	—	—	—
	Untreated	0.24	957	61	50.4	91.89			—	—	—	—	—	
MEAN	Treated	0.34	1216	39.0	249.3	24.25	3.6		0.27	1070	31.0	337.2	27.81	8.2
	Untreated	0.30	1250	42.0	134.4	52.02			0.24	1252	32.0	231.0	42.33	

Table 3
Yield characteristics, percent disease incidence and profitability of fungicide application in selected *P. megakarya* infected districts of Ghana, 1995/96–1996/97

Region/District	Treatment	Cocoa trees (ha)	Yield (kg/ha)[a]	% DI[b]	Profitability
Ashanti					
Offinso	Treated	1617	270.9	38.1	4.4
	Untreated	1558	159.2	61.0	
Tepa	Treated	1430	303.3	11.0	4.1
	Untreated	1524	217.4	32.2	
Nkawie/Kunso	Treated	1079	334.1	6.7	3.9
	Untreated	1456	278.9	25.5	
Brong Ahafo					
Goaso	Treated	1285	314.7	43.3	2.5
	Untreated	1009	183.7	61.1	
Bechem	Treated	988	344.8	23.3	3.8
	Untreated	825	144.7	51.7	
Volta					
Kpeve	Treated	1064	220.9	23.6	1.4
	Untreated	1219	193.7	50.1	
Western					
Essam	Treated	1293	624.1	46.3	5.5
	Untreated	1265	358.3	76.5	

[a] Figures are means of total yield from 5 farms in each district over the 2-yr period.
[b] Percent disease incidence.

Most of the main shade tree species on the farms in the Bechem and Hohoe districts (Table 4) were forest trees. The dominant types in the Hohoe District were *Elaeis guinensis* and *Cola chlamydantha*, while in the Bechem district, *Terminalia superba* and *T. ivoriensis* were most common. All the experimental plots had more than the recommended 15–18 shade trees per hectare and they were unevenly distributed. The mean number of shade trees per hectare was 40 and 32 in the Hohoe and Bechem districts, respectively. Observations in this study revealed that plots with very tall and well-spaced shade trees had lower levels of disease incidence compared to plots with short shade trees and thick canopies. Infections normally started on cocoa trees beneath shade trees with thick canopies and then spread out to adjacent trees.

The profitability of fungicide spraying under the different tenure and labour arrangements in the Bechem and Hohoe districts is shown in Table 5. It was more profitable for the "abusa" tenant farmers to do fungicide spraying themselves than either the farm owner or "abusa" tenant farmer hiring labour for the purpose.

4. Discussions

The recommended cultural practices in Ghana is that farmers weed their farms at least four times in the year where the cocoa canopy is not closed, remove mistletoes, excess shade, basal chupons, infected and mummified pods during and between harvesting of healthy ripe pods, and also prune interlocking branches. Farmers are also advised to harvest ripe pods at least once a month. This package of cultural practices is an essential part of black pod disease management in Ghana (Akrofi, 2000) and has been found effective against black pod disease caused by *P. palmivora* and also to enhance the effectiveness of chemical fungicides (Asare-Nyako, 1974). These management practices improve air circulation, reduce humidity and consequently, incidence of black pod. A high level of mistletoe infestation results in the degeneration of cocoa trees and high yield losses because they are parasitic and compete with the host plant for food and nutrients.

Most farmers in the Hohoe and Bechem districts weeded their farms at least once in the season, while a few, particularly in the Hohoe district only weeded around cocoa trees bearing pods to facilitate harvesting when they mature. This observation is consistent with the findings of Donkor et al. (1991) who reported that many farmers in *P. megakarya* areas weeded only once in a year. The present study has shown further that only 6 of the 22 farmers removed basal chupons on their farms. The remaining 16 believed that the chupons were potential replacements for the parent plants as they aged and died. Pruning and also the removal of basal chupons open up the cocoa canopy for more light to

Table 4
Prominent shade trees identified on farmers' farms in the Likpe Abrani (Hohoe district) and Buokrukruwaa (Bechem district) of Ghana

No.	Local name	Botanical name	Family	Suitability[a]
1.	Kesene	*Dracaena manii*	Dracaenaceae	b
2.	Kumanini	*Lannea welwitschii*	Anarcadiaceae	c
3.	Mango	*Mangifera indica*	,,	c
4.	Funtum	*Funtumia elastica*	Apocynaceae	b
5.	Kakapenpen	*Rauvolfia vomitoria*	,,	b
6.	Sese	*Holarrhena floribunda*	,,	b
7.	Akonkodie	*Bombax buonopozense*	Bombacaceae	d
8.	Onyina	*Ceiba petandra*	,,	d
9.	Yaya	*Amphimas pterocarpoides*	Caesalpiniaceae	b
10.	Emire	*Terminalia ivorensis*	Combretaceae	b
11.	Ofram	*Terminalia superba*	Combretaceae	b
12.	Fetefre	*Discoglypremne caloneura*	Euphobiaceae	b
13.	Bako	*Tieghemella heckelii*	,,	c
14.	Wama	*Ricinodendron heudelotii*	,,	c
15.	Dua bankye	*Manihot glaziovii*	,,	b
16.	Kroma	*Klainedoxa gabonensis*	Irvingiaceae	c
17.	Prekese	*Tetrapphleura tetraptera*	Fabaceae	b
18.	Okoro	*Albizia zygia*	,,	b
19.	Pear	*Persea americana*	Lauraceae	b
20.	Kyenkyen	*Antiaris toxicaria*	Moraceae	b
21.	Okure	*Trilepisium madagascarienses*	,,	b
22.	Oyankyeren	*Ficus exasperata*	,,	b
23.	Odum	*Milicia excelsa*	,,	c
24.	Abe	*Elaeis guinensis*	Palmae	c
25.	Gliricidia	*Gliricidia sepium*	Fabaceae	b
26.	Akye	*Blighia sapida*	Sapindaceae	c
27.	Hotrohotro	*Hannoa klaineana*	Simaroubaceae	c
28.	Danta	*Nesogordonia papaverifera*	Sterculiaceae	d
29.	Watapuo	*Cola gigantea*	,,	d
30.	Bese	*C. nitida*	,,	d
31.	Krabese	*C. chlamydantha*	,,	d
32.	Dadieba	*Adansonia digitata*	,,	d
33.	Wawa	*Triplochiton scleroxylon*	,,	d
34.	Foto	*Sterculia tragacantha*	,,	d
35.	Esafufuo	*Celtis wightii*	Ulmaceae	b
36.	Esa	*Celtis mildbraedii*	,,	b

[a] Suitability as shade for cocoa cultivation.
[b] Suitable.
[c] Unsuitable because of thick or large spreading crown.
[d] Unsuitable because it serves as alternative host of cocoa swollen shoot virus.

Table 5
Profitability of fungicide application under different tenancy and labour arrangements

Tenancy[a]	Labour arrangement	Profitability	
		Bechem District	Hohoe District
1. Farmer-owned	Hired labour	5.6	2.5
2. Abusa	Caretaker spraying	15.3	7.1
3. Abusa	Hired labour spraying	3.8	1.2
Mean		8.2	3.6

[a] Farmer-owned: no sharing of proceeds; Abusa: sharing of proceeds with caretaker taking one-third and land owner two-thirds.

penetrate and thereby increase yield. In spite of these benefits, the present study showed that only 10 of the 22 farmers pruned their farms.

None of the farmers managed shade nor removed mistletoes and infected pods between harvests. Their reasons were that shade trees buffered the environmental conditions during the drought period, and the removal of mistletoes and infected pods between harvests required extra labour, a practice not consistent with traditional cocoa production (Hammond, 1962).

It has been recommended (Anon, 1995) that cocoa pod husks are sprayed with recommended fungicides, buried or burnt but only a few farmers do this. The present observation is consistent with the reported non-adoption of these recommendations, since no farmer disposed of pod husks as recommended. Instead the farmers left the husks in the open at the breaking points and beneath the trees where peaks of infection occurred. The infection gradient observed in this study is expected because cocoa pod husks are themselves selective media for *Phytophthora* (Bezerra and Luz, 1993). Currently, the option of burning the husks is widely being promoted as the ash is used for making soap to add to the farm income.

The results showed no correlation between plot size and yield. Plot sizes were relatively bigger in the Hohoe district than in the Bechem district but these did not give corresponding higher yields and profit. Small-sized farms may be easier to manage. It is necessary to find out the minimum size of a cocoa farm and conditions under which fungicide application is economically profitable in such farms, in *P. megakarya* affected areas.

The study showed that none of the farmers planted exactly at the recommended spacing of 3 m × 3 m or 2.5 m × 2.5 m (Donkor et al., 1991). However, the mean plant densities (1592.5 ha^{-1} and 1388 ha^{-1} recorded in the Hohoe and Bechem districts, respectively, and 1258 ha^{-1} in the four regions) were within the range of densities required for optimum yields (1111 or 1666 trees/ha).

Fungicide spraying must not only improve yields but should also give sufficient returns if it is to be acceptable to the farmer. Moreover, the need to control *Phytophthora* pod rot disease with chemical fungicides depends on the magnitude of attack and loss of crop (Muller, 1974) as well as yield (Asare-Nyako, 1974). All these factors must be high to justify the effort and expense entailed in chemical treatment. The present study has shown that fungicide application reduces *P. megakarya* infection and increases yield. Average yields per hectare in Ghana ranges between 207 and 475 kg/ha (COCOBOD, 1998). In this study, farms in the Essam district were relatively younger (8–15 yr) and planted with hybrid cocoa, which produced pods all year round, had high yields (624.1 kg/ha) and high disease incidence (76.5%). Without fungicide application, most of the pods would have been lost to the disease. The disease incidence was comparatively lower (50.1%) in the Kpeve district where the farms were older (> 30 yr) and mostly planted with Amelonado. In spite of the low disease incidence, yield (220.9 kg/ha) and profit were low. This suggests that fungicide application on farms with low yields is not profitable. The present study has also shown that fungicide application reduces *P. megakarya* infection and increases yield, particularly when cultural practices are done.

The preference for shade trees on cocoa farms varies from one farm and locality to the other. The choice usually depends on the economic value the farmer puts on the tree. Eighteen out of the 37 forest tree species on the plots in the Bechem and Hohoe districts were not suitable for permanent shade for cocoa since they cast excessive shade on the cocoa layer (G.J. Kwapong and A.Q. Donkor, personal communication), thus enhancing spread of black pod disease (Dakwa, 1973, 1974). Shade trees in the Sterculiaceae and Bombacaceae families were classified as unsuitable for cocoa because they serve as alternative hosts of cocoa swollen shoot virus (Tinsley and Wharton, 1958; Attafuah, 1965). Most of the farmers in the study areas were unaware of the role of these trees in cocoa swollen shoot virus and black pod disease epidemiology. Discussions with the farmers also revealed that the other unsuitable trees (e.g. *Elaeis guinensis*, *Persea americana*, *Mangifera indica*, *Milicia excelsa*, *Tieghemella heckelii*, *Nesogordonia papaverifera* and *Triplochiton scleroxylon*) were left on the farms because they served as sources of food, fuelwood for domestic activities and additional income.

The canopy structure of the shade trees influences the amount of shade provided, air movement and therefore the degree of modification of the micro-climate (Ampofo, 1984). The relatively higher humidity under the short shade trees with thick canopies enhances disease development. These disease foci could be early targets for disease management, particularly, fungicide applications, to impede disease spread and reduce the cost of control.

Funtumia elastica and *Ricinodendron heudelotii* are among the desirable shade trees for cocoa in Ghana (Are and Gwynne-Jones, 1974) but they, and *Dracaena manii*, have been found to be alternative hosts of *P. megakarya*. In this study, there was no visual evidence to suggest that black pod infections of cocoa trees around these trees were greater than in other areas. The epidemiological significance of these shade trees in black pod disease development needs further investigation.

Controlling black pod with fungicides required labour input and each labour arrangement had different cost obligations for farmers and labourers. According to Boadu (1992), a share in the output gives the labourers an incentive to increase production and also spreads the economic consequences of the risks of low yields and prices between the farm owner and the labourer. Majority of cocoa farmers in Ghana are small-scale producers with less than 6 ha land holding (COCOBOD, 1998) and do not have the cash to hire labour especially outside the main cocoa harvesting season. Such farmers rely on labour provided by "abusa" tenant farmers who provide all the labour requirements (themselves and their family). The "abusa" system has aided substantially in the expansion and maintenance of cocoa in Ghana (Hill, 1962; Okali, 1983).

Farmers who hire labour are usually the few resource-endowed ones who often have security on their land and can access credit from the formal financial institutions (Asante, 1992). Some farmers are also involved in non-cocoa activities such as trading, transport or large-scale food crop production and income from these sources is often ploughed into cocoa (Asante, 1992). Unlike the "abusa" tenant farmer who had a vested interest in the farm, hired labourers had limited or no interest in the farm hence, spraying was not always efficiently done. The hired labourer was paid depending on either the area sprayed within a specified period or the number of sachets of fungicides sprayed. This emphasizes the need to ensure that people involved in the disease control programme, particularly, the use of fungicide sprays, always have a stake in farm output.

Various challenges were encountered in conducting the trials. For example, while some farmers only carried out the recommended cultural practices on the fungicide-treated plots, others sprayed the fungicide in the relatively higher bearing portions of the farm. This indicates that farmers found it necessary to protect their pods from the disease. Other farmers sprayed only in the severest black pod areas, particularly when the issue of compensating farmers' for pod losses to black pod was introduced. Some farmers also wanted to spray the untreated plots in the middle of the season when they saw the effectiveness of fungicide control on their treated plots. Resolving such issues required constant effort from extension and research staff to re-explain the trial objectives, methods and reasons for farmers' involvement. It was, however, noted that other farmers who were not involved in the trials started adopting the management practices on their farms.

5. Conclusion

The trials have provided valuable information on the effectiveness of fungicide spraying under a range of working conditions and have given a deeper insight into farmers' perceptions of *Phytophthora* pod rot management strategies. There has been a better understanding of the problems and constraints under which cocoa farmers operate. There appeared to be an information gap on *Phytophthora* pod rot disease and its management between researchers and farmers as most of the latter were ignorant of the factors that favoured disease development and spread. There is, therefore, the need to increase farmers' awareness of the disease by intensifying their education through the print and electronic media, organization of workshops, for a and on-farm demonstrations. The trials served as a useful tool for the promotion of extension messages, by providing farmers with the experience necessary for decision making as to when and how to embark on cultural and chemical control of *Phytophthora* pod rot disease, particularly the type caused by *P. megakarya*. It also provided valuable lessons to researchers involved in the development of disease control strategies that working from the farmer's perspective is essential if research recommendations are to be adopted by farmers. It was found out that involvement of farmers at all stages of the trial process from setting the agenda to interpreting the results allows for better, stronger relationship between the researcher, extension agent and the farmer.

Acknowledgements

The authors are grateful to the defunct Cocoa Services Division of Ghana Cocoa Board, staff of the Mycology Section of the Plant Pathology Division and Farming System Research Unit of CRIG for the selection of plots and collection of data. The assistance of Dr. G.J. Kwapong and Mr. A.Q. Donkor in the compilation and classification of data on the shade tree species is greatly acknowledged. Dr. J.B. Ackonor offered invaluable comments, suggestions and criticisms. This paper is published with the permission of the Executive Director, CRIG, Tafo.

References

Akrofi, A.Y., 2000. Managing by *Phytophthora megakarya* pod rot disease: the Ghana Experience. In: Bong, C.L., Lee, C.H., Shari, F.S. (Eds.), Proceedings INCOPED Third International Seminar, Kota Kinabalu, Sabah, Malaysia, 16–17 October 2000, pp. 78–83.

Akrofi, A.Y., Appiah, A.A., 1995. *Phytophthora* pod rot control trials; intervals of fungicide application trial at Tafo and Bechem. Annual Report, Cocoa Research Institute, Ghana, 1993/94, pp. 74–77.

Akrofi, A.Y., Opoku, I.Y., Appiah, A.A., 1997. On-farm farmer managed trials to control black pod disease caused by *Phytophthora megakarya* in Ghana. In: Owusu, G.K., Padi, B., Ollennu, L.A.A., Owusu Manu, E. (Eds.), Proceedings of the First International Cocoa Pests and Disease Seminar, Accra, Ghana, 6–10 November 1995, pp. 109–118.

Ampofo, S.T., 1984. The cocoa microclimate. Annual Report, Cocoa Research Institute, Ghana, 1976/77–1978/79, p. 32.

Anon, 1995. Cocoa black pod disease: a guide to farmers. CRIG Farmer's Guide, No. 9.

Are, L.A., Gwynne-Jones, D.R.G., 1974. Establishment of cacao farms. In: Are, L.A., Gwynne-Jones, D.R.G. (Eds.), Cacao in West Africa. Oxford University Press, London, pp. 50–65.

Asare-Nyako, A., 1974. Towards an economic chemical control of the black pod disease of cocoa in Ghana. Ghana J. Agric. Sci. 7, 17–23.

Asante, E.G., 1992. Benefit cost analysis of CRIG recommended cocoa production techniques in relation to farmer adoption patterns in the Ghana cocoa industry. A Paper Presented at the International Conference on Cocoa Economy, Bali, Indonesia, 19–22 November 1993.

Attafuah, A., 1965. Occurrence of cocoa viruses in wild plant species in Ghana. Ghana J. Agric. Sci. 5 (2), 97–101.

Bezerra, J.L., Luz, E.D.M.N., 1993. Fungal succession and survival of cacao pathogenic fungi on buried husks in Bahia, Brasil. In: Murray, D.B., Jones, E., Quesnel, V.C., Chalmers, W.S., Fordham, R., Iton, E.F. (Eds.), Proceedings of the 11th International Cocoa Research Conference, Yamoussoukro, Cote' D'Ivoire, 18–24 July 1993, pp. 37–44.

Blencowe, J.W., Wharton, A.L., 1961. Black pod disease in Ghana: incidence of the disease in relation to levels of productivity. Reports on Sixth Commonwealth Mycology Conference, London, 1960, pp. 139–147.

Boadu, F.O., 1992. The efficiency of share contracts in Ghana's cocoa industry. J. Dev. Stud. 29 (1), 108–120.

Brown, C.K., Annor-Frimpong, C., 1994. Socio-cultural dimensions of cocoa farming systems in Ghana: a review of the literature. Consultancy Report to Cocoa Research Institute of Ghana, 1994, pp. 8–24.

COCOBOD, 1998. Tree stock Survey Project, Final Report, GCP/INT/COA. Ghana Cocoa Board, Accra, 107pp.

Dakwa, J.T., 1973. Black pod disease and the weather. Annual Report, Cocoa Research Institute, Ghana, 1971–72, pp. 74–78.

Dakwa, J.T., 1974. The development of black pod disease (*Phytophthora palmivora*) in Ghana. Turrialba 24 (4), 367–372.

Dakwa, J.T., 1987. A serious outbreak of the black pod disease in a marginal area of Ghana. In: Machado, R.C.R., Tetteh, E.K., Adegbola, M.O.K., Bonaparte, E.E.N.A. (Eds.), Proceedings of the 10th International Cocoa Research Conference Santo Domingo, Dominican Republic, 17–23 May 1987, pp. 447–451.

Donkor, M.A., Henderson, C.P., Jones, A.P., 1991. Survey to quantify adoption of CRIG recommendations. FSU Research Paper 3, CRIG, Ghana, 12pp.

Hammond, P.S., 1962. Cocoa agronomy. In: Brian Wills, J. (Ed.), Agriculture and Land Use in Ghana. Oxford University Press, London, pp. 252–256.

Hill, P., 1962. Social factors in cocoa farming. In: Wills, J.B. (Ed.), Agriculture and Land Use in Ghana. Oxford University Press, London, pp. 278–285.

Hislop, E.C., Park, P.O., 1960. Fungicide research. Rep. W.A.C.R.I. 1960–61, pp. 96–106.

Lass, R.A., 1985. Diseases. In: Gordon Wrigley (Ed.), Cocoa, 4th Edition, G.A.R., Wood, R.A. Lass, Longmans, London, pp. 265–365.

Muller, R.A., 1974. Effect of Prophylactic Measures on the dissemination of *Phytophthora palmivora*. In: Gregory, P.H. (Ed.), *Phytophthora* Disease of Cocoa. Longmans, London, pp. 169–178.

Okali, C., 1983. Cocoa and Kinship in Ghana: the Matrilineal Akan of Ghana. Kegan Paul International, London, pp. 16–24.

Tinsley, T.W., Wharton, A.L., 1958. Studies on the host ranges of viruses from *Theobroma Cacao*. Ann. Appl. Biol. 46 (1), 1–6.