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Review

Crop protection strategies for major diseases of cocoa, coffee and cashew in Nigeria

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A great percentage of people in the developing countries are engaged in agriculture, but the yields of their produce are low due to diseases that plague their crops. In Nigeria, crop protection measures that are cheap, simple, cost-effective and sustainable are desirable to combat *Phytophthora* pod rot (black pod) and cocoa swollen shoot virus diseases of cocoa, coffee leaf rust and coffee berry diseases, inflorescence blight disease of cashew in order to make farming profitable and sustainable. Disease control strategies include the use of resistant cultivars, chemicals, biological, botanicals, cultural, physical controls and application of biotechnology, each of which is discussed in this paper.

Key words: Crop protection, cocoa, coffee, cashew, diseases.

INTRODUCTION

Among the objectives of Cocoa Research Institute of Nigeria, which was established in 1964, is the identification of the ecology and methods of control of pests affecting her mandate crops: cocoa, coffee and cashew. Smallholder farmers in Nigeria produce these cash crops, which have contributed to the economy of Nigeria as foreign exchange earners and as sources of raw materials for local industries among which are cocoa industries, confectionery, beverage and winery industries (Oloruntoba, 1989). Yields of these crops are lower than those recorded in other countries where they are cultivated. One of the major reasons for the poor yield is diseases and pest, which have been estimated to cause 20-30% crop losses.

Plant pathologists visualize the components of disease as a ‘disease triangle’ consisting of host, pathogen and environment (Agrios, 1988). For a disease to occur, these components have to be susceptible, virulent and favorable, respectively. The modification, removal, reduction, or elimination of any one of the components, as a management strategy could control the disease.

High crop yields can be achieved with sustainable agriculture if plants are protected from diseases and pests (Cook, 1986). This will make plants to grow well, take up nutrients, compete with weeds and yield to the limit of their environment. Therefore, small-scale farmers require crop protection measures that are cheap (so that farmers can afford them), simple (so that they can be applied under particular circumstances), cost-effective (so that they can enable farmers to make profits and prosper), and sustainable (so that the production is also sustained). This review focuses on major diseases of cocoa, coffee and cashew in Nigeria towards which the use of resistant cultivars, chemical, biological, cultural and physical controls have been directed with some practical success.

COCOA

Nigeria is currently the 4th largest world producer of cocoa (*Theobroma cacao*) with 165,000 metric tones in 1999/2000 (FAO, 1996; Taylor, 2000); the yield is 338 kg/ha/yr (Table 1). Depending on where cocoa is grown, one or more of the three diseases (black pod caused by species of *Phytophthora*, witches’ broom caused by *Crinipellis perniciosa*, and frosty pod rot caused by *Moniliophthora roreri*) may reach epiphytotic proportions that cause devastating losses (Evans, 2001; Bowers et al., 2001). Taylor (1998) reported that in Africa, Brazil

Table 1. Production figures, yield and major diseases of cocoa, coffee and in Nigeria.

Parameters	Cocoa (*Theobroma cacao*)	Coffee (*Coffea arabica*/ *C. canephora*)	Cashew (*Anacardium occidentale*)
Production figures	165,000 MT[1]	3,000 MT[2]	25,000 MT[2]
Yield	338 kg/ha/yr[1]	394 kg/ha[1]	1.0-1.35T/ha[2]
Major diseases	(1) PPR (2) CSSV	CLR (2) CBD	Inflorescence blight
Causal agents	*Phytophthora megakarya* Vectors:(mealybugs)*Planococoides njalensis, Ferrisiana virgata,* Nematodes	(1)*Hemileia vastatrix* & *H. coffeicola* (2) *Colletotrichumum coffeanum*	*Lasiodiplodia theobromae*

PPR= *Phytophthora* pod rot
CSSV= Cocoa Swollen Shoot Virus
CLR=Coffee leaf rust
[1]FAO (1996)
[2]CRIN (2000)
CBD= Coffee Berry disease

and Asia, black pod disease reduced production by 450000 tons costing about $423 million. *Phytophthora* pod rot (Ppr or black pod) and cocoa swollen shoot virus (CSSV) are the two diseases considered most important and have received great attention in Nigeria. *Phytophthora* pod rot caused by *P. palmivora* and *P. megakarya* (Sansome et al., 1975; Brasier and Griffin, 1977) is currently the most important yield-limiting factor in the Nigerian cocoa industry, with total annual losses estimated at up to 30 to 35% of the nation's crop (Gorenz and Okaisabor, 1971), while 30-90% of the total global crop loss is caused by this disease (Bowers et al., 2001). However, severity of this disease varies depending on climatic conditions (rainfall and humidity) and the variety of cocoa being grown. *Phytophthora* spp. also causes seedling diseases and cankers of stems, trunks and crowns of cocoa trees. The sources of inoculum for Ppr are soil, infected flower cushions, ant tents, dry pods on the cocoa trees/ground/ debris formed from heaping of cocoa pod husks, while spread from infected pods is by water splash and drips during rains, living vectors, wind blown sprays and wounds on pods by knives, rodents or insects (Purdy, 1999; Maddison and Bicknell, 1979; Maddison and Ward, 1981; Gregory, 1981).

Control measures for black pod

The use of resistant varieties: This is the most applicable, low cost to farmers and attractive disease control technology. Governments and private companies in developed countries invest heavily in this and have produced most encouraging output by contributing significantly to increased productivity. However, the process is often quite slow and laborious. It does not offer an immediate solution to a serious disease problem, which in most cases requires urgent action. Adebayo (1973, 1974 and 1975) evaluated 12 cocoa cultivars with moderate tolerance to Ppr infection, while five showed high resistance. Olaniran et al. (1977) however, obtained clones that combine high pod productivity with P*hytophthora* black pod resistance/tolerance, while Williams (1979) selected some "escapes" which are high yielding progenies. Twenty-eight progenies of cocoa hybrids were evaluated for resistance to *P. megakarya* using the leaf disc inoculation technique and 4 clones were found resistant (Badaru and Fawole, 1999). Sixteen budded "T" clones were also tested; only one clone was resistant with small expanding lesions (Badaru and Fawole, 1999). Also, Badaru and Aikpokpodion (2001) reported that materials with outstanding escape characteristics are in the germplasm and Ppr escape clones would be released at the end of the assessment of 265 genotypes.

Cultivars tolerant of the fungal diseases are largely unidentified or have not been propagated in sufficient quantities." Resistance breeding for the disease is currently the major priority in West Africa where the virulent *P. megakarya* is proving difficult to control. Active research is underway throughout the world on genetic resistance to control black pod disease of cocoa.

Chemical Control: The use of chemical pesticides (copper and metalaxyl-based fungicides) is short term solutions, but generally most reliable and popular with farmers because of their quick, effective action. But it is now known that with non-target effects and resistance of the pathogen, the risks to human lives and to the environment is so great that there is no longer any question about the necessity for changing to crop protection techniques which are less dependent on chemicals (Sengooba, 1992). The spraying of copper-based fungicides (Table 2) to the pods is the most

Table 2. List of chemicals recommended for the control of *Phytophthora* pod rot (black pod) disease of cocoa (*Theobroma cacao*).

Trade name	Active ingredient	Rate (g /9 l water)	References
Brestan	Triphenyltinacetate	13.5	Adegbola (1985), Adeyemi (2000)
BBS Procida	Copper sulphate	90.0	Adegbola and Filani (1984), Adegbola (1985, 1993)
Bordeaux mixture	Copper sulphate + calcium hydroxide	90+36	Adegbola and Filani (1984), Adeyemi (2000)
Caocobre-Sandoz	Cuprous oxide	43.3	Adegbola (1985), Adegbola and Filani (1982)
Copper Nordox	Copper hydroxide	45.0	Adeyemi (2000)
Kocide 101	Copper hydroxide	40.5	Adegbola (1985) Adeyemi (2000),
Orthodifolatan (Captafol)	4-Cycloxexene cis-n-Ci-dicarboximide	45	Adegbola and Filani (1984), Adegbola (1985)
Macuprax	Copper sulphate	90.0	Adegbola and Filani (1982, 1984)
Perenox	Cuprous oxide	40.0	Adeyemi (2000), Adegbola (1985, 1993)
Ridomil Plus	Cuprous oxide + Metalaxyl	30	Adegbola and Filani (1982)

reliable control method available for susceptible cocoa cultivars to *Phytophthora* pod rot. The standard practice is fungicide application at 3 weekly intervals beginning from the onset of rains (in April) until about first week in November (Adegbola and Filani, 1984; Adeyemi, 2000). The frequency and time of spray application have also been reported to affect the effectiveness of the fungicides (Adegbola, 1993). The problems associated with spraying include excessive tree height which makes infected pods disperse inoculum from high in the canopy, cost of chemicals, labour and poor cocoa prices. Also in wetter areas the chemicals are often washed off by heavy rains and need to be repeated. Therefore this control method is not entirely effective; it is expensive for the small farmer and therefore not economically feasible.

Cultural control: This involves manipulation of the environment to make it unfavorable for establishment of the pathogen. Cultural operations involves farm sanitation through weed control by slashing of the weeds (with sharp cutlass) and removal of vegetative part of the plant (pruning). These are routine practices to remove shade and control the height of cocoa tree to give the desired shape and ventilate farms to reduce relative humidity, disease and pest incidence (Adeyemi, 2000). Short trees are easier to spray, harvest and sanitize. Light pruning is done any time of the year while heavy pruning is carried out during the rainy season (April to October). Unnecessary branches including chupons, fan branches and flushes arising from the base and sides of the cocoa stems, epiphytes and parasites such as orchids and mistletoe are removed (Adenikinju et al., 1989). Regular harvesting of infected pods is essential and pod husk heaps should be removed or sprayed during normal spraying. The pod husks should not be buried as it increased pathogen population in the soil (Adebayo, 1974; Griffin, 1977).

The use of botanicals: In Nigeria and many other developing countries, the use of many plant species as both pesticides and local medicines has been reported. Plants can provide less phytotoxic, more systemic and easily biodegradable fungicides (Dixit et al., 1978; Adejumo, 1997). Local herbs and constituents of plant materials offer cheap and safer control for those categories of farmers who cannot afford the present high cost of synthetic pesticides.

"Tiwantiwa", a herbal plant mixture containing roots of four trees and leaves of another set of herbal plants of different known weights was developed by a peasant farmer at Akure, Ondo State in 1988 as a treatment against black pod disease of cocoa. It was evaluated both at the laboratory and on the field at the Cocoa Research Institute of Nigeria, Ibadan. Olunloyo (1994b) reported 10% of the extracts as the minimum concentration at which zone of inhibition could be detected, the compound is a diterpinoid and that there was no significant difference between the performance of 20% herbal extracts and Bordeaux mixture on the field. Two cocoa varieties reacted differently to *P. megakarya* infection, and the level of control obtained was related to the intensity of rainfall in each ecological zone (Olunloyo, 1997b). Also, Adejumo (2000a) reported the potentials of *Chromolaena odorata* and *Piper guineense* in controlling black pod disease.

Cocoa swollen shoot virus (CSSV)

Cocoa Swollen Shoot Virus (a member of the badnavirus group) was first reported on cocoa in West Africa and in Nigeria in 1936 and 1944, respectively (Murray, 1945; Adegbola, 1971). Among all the regional diseases of cocoa, CSSV is probably of greatest importance (Pereira, 1996), while Thresh (1991) reported that the disease is the most intractable and destructive to strike at the cocoa industry in West Africa. Countries mainly affected are Ghana, Togo, Cote d'Ivoire and Nigeria. The economic importance is evidenced by the serious decline in cocoa production experienced in these countries. In Nigeria, large areas have been abandoned due to the devastation by CSSV in places referred to as 'areas of mass infection'. The abandoned areas in Nigeria contain the best available cocoa soils involving an area of approximately 172,500 acres (69,638 ha), while about 5,000,000 trees were reported infected in Ibadan Division alone (Thresh, 1959). The effect of the virus currently in Nigeria is relatively weak compared to the virulent strains found in Ghana. It is found only where trees are attacked simultaneously by mirids (capsids) that the virus infection accelerates the decline and occasional death of the trees. Mealybugs including *Planococcoides njalensis*, *Ferrisiana virgata* and *P. citri* transmit the disease. Soil-inhabiting nematodes have also been reported as active transmitting agents (Lana and Adegbola, 1977; Afolami, 1980). Symptoms include red vein-banding interveinal chlorosis, immature flush leaves, leaf mosaic, development of swellings at nodes, inter-nodes, apex of stems and roots, malformation in some of the pods produced by infected trees and in cases of severe virus attack, death of infected trees. The most economically important insect pest of cocoa in Nigeria is the brown cocoa mirid (*Sahlbergella singularis* Hagl.) (Idowu, 1989). Death of CSSV infected plants has been found to be combined effort of capsids-*Distantiella theobroma* and *S. singularis* and *Calonectria rigidiuscula* (Longworth, 1963). Control measures for CSSV includes the following:

The use of resistant varieties: Great attention was devoted to selection of progenies resistant to CCSV. Atanda (1972) reported that clones C77 x C23, C73 x C25, C75 x C14, C68 x C26 and C67 x C77 were resistant, and have been distributed to farmers for planting in areas of mass infection. Tolerant progenies include T10/10 x T9/15, ICSI x Na32, C72 x C25 and C6 x C24.

Chemical control: Among the popular insecticides used in the control of vector of CSSV in Nigeria (*mealy bug, P. njalensis* inclusive) are Elocron 75 WP, Undeen 20 EC and Dursban 48 EC (Idowu, 1989). However, there are disadvantages associated with the use of chemicals including the possible toxicity to human beings, the evolution of resistant pest strain, and tainting of beans in treated cocoa, apart from being costly and unaffordable to farmers.

Biological control: Adegbola (1973) protected cocoa trees using the mild strains of the CSSV against more virulent and related strains. However, this method is limited as a means of control. This is because of the risk that the virus, mild in cocoa, may damage other crops, and also the possibility of mutation into virulent strains if widely disseminated on million of plants (Broadbent, 1964).

Physical control/Rehabilitation of cocoa farms: The eradication/removal of infected trees has been the basic method of control for CSSV infected trees in Nigeria since 1946. This is done by uprooting all the obviously infected trees and surrounding area of up to 30 m (Adegbola, 1971). Replanting with improved virus tolerant/resistant varieties follows. Gradual removal of infected trees over a number of years with improved varieties in the shade of old trees or coppicing of the old trees have been recommended (Adegbola, 1989; Adeyemi, 2000). However, Ollenu et al. (1989) and Thresh et al. (1988) emphasized that successive campaigns of eradication have failed so far due to the use of cocoa cultivars with moderate tolerance as planting material after eradication.

Biotechnology

Plant tissue culture is a method being used to obtain pathogen or virus-free clones of economically important plants. Studies have been carried out at CRIN on cocoa micro propagation (including germination) to produce clones as cells, somatic embryos (sexual embryos (seeds) without testa *in vitro*) and plantlets (Esan, 1977. 1982) and also *in vitro* germplasm conservation. Also, Adenikinju et al. (1989) reported that in CSSV research, there was recovery of virus-free plants from virus infected indexed cocoa in premium elite stocks.

Integrated pest management (IPM)

An Integrated pest management program for the control of cocoa diseases must emphasize the integration of all available control methods into a single program. Control measures being investigated include biological control microorganisms, genetic and induced resistance, cultural

Table 3. List of chemicals recommended for the control of coffee leaf rust and coffee berry diseases.

Trade name	Active ingredient	Rate g/9l water	References
Copper sulphate *, **	Copper sulphate	90	Fawole (2001)
Bordeaux mixture*	Copper sulphate + calcium hydroxide	90.0 + 36	Filani (1990a and b)
BBS Procida	Copper sulphate	90	Filani (1990a and b)
Brestan	Triphenyltinacetate	13.5	Filani (1990a and b)
MacKechney	Copper	90	Filani (1990a and b)
Kocide 101**	Copper hydroxide	40.5	Filani (1990a and b)

*Coffee leaf rust
**Coffee berry disease

practices, natural products, and limited use of chemicals (Krauss and Hebbar, 1999). In this program, reduction of the overall use of fungicides to an absolute minimum is emphasized, while maximizing their benefits. Various cultural techniques include shade reduction, regular harvesting and frequent weed control, and other agronomic practices as well as choice of resistant cultivars (Anonymous, 2001).

There are cooperative research efforts that include various national and international research institutes with a goal to identifying biological control strategies to be used in the integrated pest management systems to fight cocoa diseases.

COFFEE

Coffee, *Coffea canephora* Pierre (Robusta coffee) is cultivated widely in scattered areas in the hot humid southern parts of Nigeria. However, *C. liberica* is produced on small scale and restricted to a few states, while *C. arabica* is grown exclusively on the Mambilla plateau in Taraba State (Filani, 1989). Coffee is an important foreign exchange earning crop in Nigeria (Williams, 1971) and presently, it is cultivated in more than 20 states covering an area of over 5,000 hectares. Production figure is 3,000 metric tonnes, while yield is 94 kg/ha (Table 1).

The major diseases of coffee are the leaf rusts: orange and grey rusts caused by *Hemileia vastatrix* B. and Br. and *Hemileia coffeicola* Maub. and Roger respectively. The latter is restricted to the nursery (Filani, 1990a). The second major disease is the coffee berry disease caused by *Colletotrichum coffeanum* Noack (Fawole, 1999). *C. arabica* is susceptible to leaf rusts, while *C. canephora* and *C. liberica* are generally tolerant (Filani, 1989). Symptoms of orange leaf rust include pale yellow spots on upper surface of leaf and powdery orange colored spores (uredospores) produced by the fungus on the lower leaf surface, while grey rust is characterized by grey spots on upper surface of the leaf and closely set grey clumps of uredospores on lower leaf surface. Symptoms of coffee berry disease on green berries include brown spots, at advanced stage; the berry turns completely brown to black with the beans inside destroyed.

Chemical control: Seven fungicides including the copper-based formulations (Bordeaux mixture, BBS Procida: factory mixed Bordeaux mixture, Kocide and Mac Kechney) and organic formulations (Sicarol, Orthodifolatan and Brestan) were tested at CRIN between 1982 and 1990 for effectiveness in the control of coffee leaf rust (LR) and coffee berry disease (CBD)(Table 3). Filani (1990a, b) reported that Bordeaux mixture and BBS Procida were the most effective and therefore recommended for use by coffee farmers for LR. In another fungicide tests between 1995 and 2000, Fawole (2001) reported a cost-effective rate of 90 g/9 l application of copper sulphate for the control of LR and CBD at 3-weekly intervals.

Cultural control: Mulching has been considered as the most influential soil treatment that can be applied to ensure the most economic production over a long period. It conserves soil moisture during the dry season (November to March), increases nitrogen fixation in the soil, reduces soil temperature and supplies the needed humus to the soil (Filani, 1989). This practice enables the plants to withstand the effects of infections particularly during the dry season. Careful pruning and shading is important cultural practices for the control of coffee diseases. Effective control of grey rust was achieved in the nursery by drastically reducing the amount of shade over the seedling beds, reducing the amount of watering and spreading apart all densely packed seedlings (Filani, 1978).

CASHEW

Cashew, *Anacardium occidentale* L., is a crop with high potential for foreign exchange and a source of raw materials for Nigeria and other tropical countries

(Olunloyo, 1975). The crop grows well in mangrove forest areas to middle belt savanna zone to northern Sahel savanna area in all the agroecological zones in Nigeria. In some areas, cashew trees are planted as shade and backyard trees. Current production figure is 25,000 MT, while yield is between 1.0 and 1.35 T/ha (Table 1). Nigeria has recognized the potential economic value of cashew and has made a concerted effort to improve production of the crop.

Inflorescence blight caused by *Lasiodiplodia theobromae* is a major limiting factor affecting cashew nut production in Nigeria, causing 40-45% crop loss annually (Olunloyo, 1979). Symptoms include withering of petals and other parts of the flower, followed by a progressive dieback of the small peduncles from the tips and downward to the main floral shoots. The disease spreads through insects, which create wounds predisposing inflorescence axes to infection.

The use of resistant varieties: Ten cashew genotypes screened for relative tolerance to inflorescence blight disease and were further observed in 1993 for stability of their tolerance to the disease after 5 years. Genotypes 2Sc Eruwa, 1 Eruwa 188/276, 1sc Iwo 79/89 and Iwo 245/262 showed tolerance and could be used in future breeding programs (Olunloyo, 1994a).

Chemical control: Olunloyo (1983) reported that the addition of an insecticide (gamma-BHC) to a fungicide (Captafol) at 1.0 g/l and 1.5 g/l, respectively, protects the cashew inflorescence against the insect infestation preceding fungal attack on the panicles and thereby increased yield. A spray program consisting of a pre-bloom application followed by a full-bloom treatment of benomyl (Benlate 50WP) and dimethoate (Rogor 40) at 1.5 g a.i./l and 1.0 g a.i./l, respectively, provided greater protection against the disease (Olunloyo, 1997a). However, the extended period during which the inflorescence is susceptible to disease because of irregular flowering would necessitate multiple applications of the chemical mixture. Therefore, 3-4 sprays are recommended during the flowering season. Azam-Ali and Judge (2001) reported that control of affected branches should involve pruning and spraying with 1% Bordeaux mixture or other copper-based fungicides.

Cultural control: Fertilizer application has been used to reduce disease severity of certain crops and thereby increase productivity. Experiments are in progress at CRIN to assess the effect of NPK fertilizers in reducing inflorescence blight disease of cashew and consequently increase yield.

The use of botanicals: I have previously reported (Adejumo, 2000b) the results of laboratory screening of some plants: *Allium sativum, Chromolaena odorata* and *Piper guineense* against inflorescence blight disease of cashew. I observed that *P. guineense* showed promise in controlling the disease. Field application of *P. guineense* as a spray at 5% and 10% and combination of garlic (*A. sativum*), *P. guineense, Ocimum gratissimum* and *C. odorata* at 5%, 7.5% and 10% reduced incidence of the disease and increased yield compared to the control (Adejumo and Otuonye, 2002).

CONCLUSIONS

Nigerian farmers generally believe that chemical control of diseases (especially *Phytophthora* pod rot) is dangerous coupled with unavailability of chemicals and high costs. Nevertheless, the preconceived desire for on-the-spot results makes them prefer chemical approach at all costs. But the apparent failure of conventional control methods to halt the progress of diseases on crops has led to the search for alternative control strategies in order to adopt the principles of sustainable agriculture and reduction/elimination of pesticide use. Holmes and Evans (2001) recently reported that copper-based products have now been included in the list of chemicals to be withdrawn from circulation within the next five years. Hence, short-term alternative strategies are urgently needed for the control of important diseases of crops, especially in cocoa and coffee where these chemicals are greatly being used.

Classical biological control approach utilizes the endophytes (fungi which lie asymptomatically within the host plant for all or part of their life cycle such as *Acrimonies* spp. in Gramineae) and mycoparasites/antagonists (examples are *Trichoderma* and *Gliocladium*) on the causal agents of important diseases of cocoa, coffee and cashew. This can offer promises and may provide ecologically sound control. Another possible area of control of important diseases of these tropical crops is the integration of chemical fungicides and biocontrol agents. Implementation should be based on microclimatic conditions to ensure optimum activity. By combining the two control methods, farmers can minimize their dependence on chemical control and this will result in superior disease suppression, thus minimizing yield loss.

Combination of biocontrol preparations with other control means, such as tolerant cultivars, cultural practices or hygienic measures can further minimize dependence of farmers on chemical fungicides. Setting up of regional working group on biological control is therefore imperative. This group will evaluate and promote a number of components that are suitable for sustainable disease management. Organic methods of crop production using animal manure, green manure and lime improve soil characteristics in small scale farming and thereby can also reduce the incidence and severity of pathogens in cocoa, coffee and cashew fields. Suitable materials, soil and nutrition management, weed control, pest and disease control are important aspects towards production of organic crops following international regulations. Preventive strategies for CSSV rely on breeding resistant varieties and control of the vector or early identification of disease. The latent infection of trees is known to be a problem and it has been established that latently infected trees can act as a source for further transmission (Legg, 1982). Emphasis of recent CSSV research has been on detection of infection in the latent stage before any symptoms manifest using various immunological tests.

Sound agronomic knowledge about the plantation (tree spacing, shade, soil fertility, nearness to neighboring diseased plantations, incidence and severity of pests and disease in the plantation, time of harvest, pruning intensity) is also essential for good management and sustainable production of cocoa. It is evident that a range of IPM methods are currently available to farmers but it is equally apparent that a distinct lack of extension exists at farm level across the smallholder community. The challenge is to develop extension systems which are cost effective and are able to empower thousands of small-scale farmers in IPM strategies. Farmer-participatory training systems, like the Farmer Field Schools, which have proved successful in the production of coffee in Kenya, may provide a solution (Anonymous, 1992).

Bowers et al. (2001) highlighted that optimum disease management strategy would be to identify beneficial microorganisms that persist in the cocoa canopy and root systems and provide disease control without regular spray applications. It is possible that microorganisms that induce resistance to disease and insects in cocoa can be identified. The use of these microorganisms could result in long-term disease control with limited cost to the farmer and could actually be beneficial to the environment.

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