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Control of cocoa swollen shoot disease by eradicating infected trees in Ghana: A survey of treated and replanted areas

H. Dzahini-Obiatey*, G. Akumfi Ameyaw, L.A. Ollennu

Cocoa Research Institute of Ghana, P. O. Box 8, Akim Tafo, Ghana, West Africa

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Abstract

Cocoa farms that had been treated and replanted in Ghana during the most recent phase of the cocoa swollen shoot virus (CSSV) eradication campaign were surveyed. Farms that were replanted close to adjoining old cocoa farms or which contained old trees were common in most (38) of the 41 cocoa farms surveyed. CSSV infections were apparent in 20 (53%) out of these 38 farms and they pose a serious risk of causing early infections of the re-planted farms. Control strategies that isolate the newly planted farms by a boundary of immune crops as barriers to reduce CSSV re-infection are discussed.

1. Introduction

Cocoa swollen shoot disease (CSSD) is caused by *Cacoa swollen shoot virus* (CSSV) (of genus *Badnavirus* (Lot et al., 1991); family *Badnaviridae*). The disease is one of the most devastating scourges of cocoa that in the 1940s threatened to wipe out the cocoa industry in what is now Ghana. Since the discovery of the disease in Ghana in 1936 (Stevens, 1936), the government has devoted much attention to combat CSSD. Thus, financial resources and personnel that could have otherwise been used to improve the standard of husbandry, raise cocoa production and also bring about improvement of other crops in the agricultural sector have been diverted into eradicating the disease by cutting out diseased and at times neighbouring 'contact' trees (Owusu, 1983; Owusu et al., 1996).

A massive nationwide eradication campaign began in 1946 after Posnette (1940) showed the swollen shoot and dieback disease to be caused by a virus that is spread from tree-to-tree by several species of mealybugs (Pseudococcidae). The eradication campaign has continued to the present time but there have been serious interruptions and discontinuities as discussed in previous reviews (Owusu, 1978, 1983; Thresh and Owusu, 1986; Thresh et al., 1988a; Ollennu et al., 1989 a, b). The history of the campaign has however been characterised by innovations such as (1) the introduction of block plantings in the 1950s (Owusu, 1983), where large areas lands were cleared and replanted in contiguous blocks; (2) the "plant-as-you-cut" scheme in the 1970s (Thresh et al., 1988a), under which the government cut, replanted and maintained the farms for sometime before returning them to their owners; (3) the Suhum rehabilitation project funded by the World Bank (Owusu, 1978), where the World Bank sponsored the cutting out of diseased farms and replanting them in blocks with fast growing and early cultivars.

Currently (beginning in the year 2000), the *European Union-STABilisation des recettes. d'Exportation* (EU-STABEX) is funding the control of the disease in the "scattered-outbreak areas" (i.e., areas where the disease is less widespread than in "the area of mass infection" but occurs in groups of outbreaks). The objective of the EU-STABEX funded project is to treat thoroughly all CSSD outbreaks in the scattered-outbreak areas of Ashanti, Brong Ahafo, Volta and Western Regions and also in the "*cordon sanitaire*" (the cocoa farms between the scattered-outbreak areas and the most severely affected areas), which are the northern parts of Central and the south-western parts of Eastern Region respectively (Fig. 1). The most severely

*Corresponding author. Present address: School of Biological Sciences, University of Reading. Tel.: +44 07843971176.
E-mail address: h.k.dzahiniobiatey@reading.ac.uk (H. Dzahini-Obiatey).

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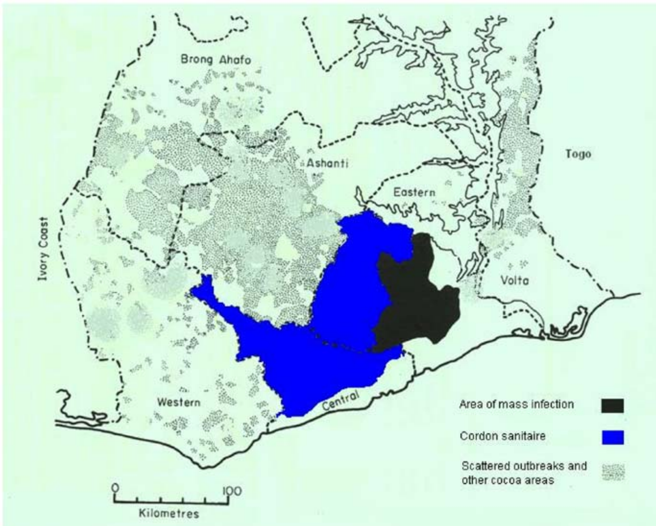

Fig. 1. A map of southern Ghana showing the newly designated *cordon sanitaire* separating the area of mass infection (AMI) from the scattered outbreaks areas elsewhere.

affected, "areas of mass infections" (AMI), in the south-eastern parts of the Eastern Region are excluded from the project because the disease is so widespread there that it is uneconomic to control it there. This paper assesses the swollen shoot situation in the treated areas of Ashanti, Brong Ahafo, Central, Eastern, Volta and Western Regions of Ghana, and suggests remedies to mitigate the adverse findings.

2. Materials and methods

2.1. Field visits, inspections and sampling

Field visits were made to the scattered outbreak areas of Ashanti, Brong Ahafo, Volta and Western Regions and the *cordon sanitaire* (Central and northern parts of the Eastern Region). Despite severe logistical constraints, three or more farms were visited in each Region. The farms visited had been treated (cut out of infected trees) and replanted within the last 3 years. Each farm visited was inspected thoroughly by a team comprising experienced disease spotters, grafters and research officers from the Cocoa Research Institute of Ghana (CRIG). The activities carried out on each farm included:

- Inspections along the boundaries of the newly replanted farms for any remaining old cocoa trees.
- Recording the proximity of the newly planted seedlings to the old cocoa at the farm boundaries.
- Inspecting thoroughly all the old trees for any visible symptoms of CSSD.
- Collecting random samples of budwood from the remaining old cocoa trees with no visible symptoms for CSSV indexing.
- Examining the replanted seedlings for visible symptoms of CSSD.
- Collecting random samples of budwood from recently planted seedlings with no visible symptoms near the boundaries for CSSV indexing.
- Thorough inspection of old cocoa within newly replanted areas for visible symptoms and the collection of budwood from symptomless trees for CSSV indexing.
- Recording the presence or absence of known alternative hosts of CSSV.

2.2. CSSV-indexing

The indexing experiment conducted was not a large-scale investigation on how many of the symptomless apparently healthy old cocoa farms had infections, since many of these cocoa farms had already been seen with infections. It was to show that some of the seemingly healthy farms could also have been affected and therefore be sources of inoculum for infecting young seedling replants. Thus, three plants were randomly picked from some of the apparently healthy adjoining old cocoa farms that were selected for indexing from each region. In the case of the newly planted farms, farmers resented the destructive sampling of the young plants and so collection of budwood from them was restricted to the few seedlings at the early jorquette stage that have developed more than one stem. All samples of the budwood taken were cut into short pieces, tied together and carefully labelled and stored moist with water-soaked absorbent cotton wool until taken to the research station at Akim Tafo. Budwood of each stem was patch-grafted to 10 Amelonado (the most susceptible indicator cocoa cultivar) seedlings and kept in an insect-proof gauze house and subsequently observed for symptoms of CSSV. The standard assessment method for CSSV, which is the appearance of red-vein banding in tender leaves followed by either severe chlorosis or vein clearing in the mature leaves within three months after inoculation was used in assessing the indexed plants.

3. Results

3.1. Field observations

The newly planted farms that were surveyed ranged in size from 0.2 to 10 hectares (0.25–10 ha) and were about 1–2 years old. Other observations made are summarised in Table 1. Most of the replanted farms bordered old cocoa: 67%, 75% and 90%, in Eastern, Central and Brong Ahafo regions, respectively and 100% in Ashanti, Volta and Western Regions. The proportion of the perimeter of the newly planted farms that bordered old cocoa ranged from a quarter to total, thus, exposing newly planted seedlings to the old and often infected trees around the boundaries. Most of the completely surrounded farms were in Ashanti Region and were of about mean size and age of 0.25 ha and

Table 1
State of the CSSD-treated and replanted farms in the scattered outbreak areas of six regions of Ghana

Regions	Total number of farms visited	Recently planted farms with at least one boundary bordering an old cocoa farm			Farms not bordering old cocoa farms
		Old adjoining farms with visible symptoms	Old adjoining farms without visible symptoms	*a*+*b*	
Eastern[a]	3	1{50[b]}	1	2 (67[c])	1
Central[a]	4	2{67}	1	3 (75)	1
Ashanti	8	4{50}	4	8 (100)	0
Western	5	5[d]{100}	0	5 (100)	0
Volta[e]	11	0{0}	11	11 (100)	0
Brong Ahafo	10	3{33}	6	9 (90)	1
Total	41	15{39}	23	38 (93)	3

[a]Farms visited in these areas of Eastern and Central regions are in the nationally designated "*cordon sanitaire*".
[b]Percentage of old adjoining farms containing obviously diseased trees.
[c]Figures in brackets represent percentage of replanted farms that are adjoined by old cocoa.
[d]One of the seedlings indexed in one of these re-planted farms expressed CSSD.
[e]Funding was provided by the EU-STABEX project except in the Volta Region where activities were funded by the Ghana Government.

Table 2
CSSV indexing of cocoa trees from some of the apparently healthy adjoining old cocoa encountered in the survey

Regions	No. of apparently healthy farms tested	No. found to be infected upon indexing	Final percentage of infected old adjoining farms (i.e. obviously visible + indexed farms)	Types of symptoms observed upon indexing
Ashanti	2	1(13.3[m])	63	Red vein banding, vein clearing
Brong Ahafo	5	2(15[m], 3.8[n])	44	Red vein banding; vein clearing
Central	2[a]	1(6.7[m])	100	Red vein banding, vein clearing, severe chlorosis
Eastern	1	1(5.6[m])	100	Red vein banding, severe chlorosis
Western	ND	ND	100	ND
Volta	5[a]	0	0	No symptoms
Total	14	5	53	

Figures in brackets are the infection rates of test (indexed) plants showing symptoms of CSSV expressed in percentages: m = budwood from an older tree in adjoining old farm; n = budwood from a young seedling in a replanted farm.
ND: not done because all the adjoining farms had infections with visible symptoms.
[a]Includes test on budwood taken from young cocoa seedlings underneath *Cola gigantea* trees.

1.5 years, respectively. Fifteen (39%) of the 38 old cocoa farms adjoining the newly planted ones were apparently infected with visible symptoms and were distributed among the regions as follows: Western 100%, Central 67%, Ashanti 50%, Eastern 50%, Brong Ahafo 33% and Volta 0%. In all the replanted cocoa farms visited, the newly established seedlings were planted up to the boundaries of the site and in some cases the branches of the adjacent old cocoa overhung the seedlings. A 1-year-old seedling in one of these farms was found with conspicuous symptoms of CSSD including shoot die back, stem swellings and severe chlorosis of the matured leaves.

Cola gigantea, a known alternative tree host of CSSV, was found growing within replanted seedlings in Central and Volta regions: two trees were in separate farms in the Volta Region while one was found in a farm in the Central Region. The average diameter of these trees was 0.9 m at breast height (dbh) with a canopy spread of about 9 m, thus, effectively overhanging about 30 newly planted seedlings. However, a thorough inspection of the seedlings around them did not show any visible symptoms of CSSD and subsequent virus indexing of the budwood taken from them did not confirm any infection. No budwood from seedlings underneath *C. gigantea* tested positive, i.e., were infected.

3.2. Virus indexing

Table 2 show the results of the indexing experiments carried out on apparently healthy old cocoa farms adjoining the newly planted ones. Five out of the 14 farms were found to be infected. The infection rates were rather low (3.8–13.3%) but the symptoms expressed were unequivocally CSSD. These results bring the cumulative number of infected old cocoa adjoining newly planted ones to 20, i.e., 53% of all the adjoining old cocoa farms encountered. All the farms in Eastern, Central and Western Regions were infected and the proportions in Ashanti increased from 50% to 63% and in Brong Ahafo from 33% to 44% when latest infections were included.

4. Discussion

Old infected cocoa trees bordering newly planted stands have long been known to be the immediate source of CSSV infection in Ghana (Hammond, 1957; Owusu, 1978; Legg et al., 1981; Ampofo and Osei-Bonsu, 1988; Ollennu et al., 1989a) and Nigeria (Adegbola, 1977). However, in replanting CSSV-treated farms or when establishing new farms in CSSV-endemic areas, steps have seldom been taken to avoid this important source of re-infection. Planting of most cocoa farms is usually carried out to the boundaries of the site in close proximity to old cocoa even in the CSSV-endemic areas where infection is prevalent. In the current EU-STABEX CSSV eradication project, cocoa is still being replanted very close to old cocoa trees. The fact that at least 53% and sometimes all adjoining old cocoa assessed in the survey was infected; 39 of them visibly so and the rest determined after indexing is very disturbing since this is a major source of re-infection of newly established cocoa. The most worrying aspect is that 30–100% of the visibly infected farms were in the most endemic regions and in many cases, the old cocoa trees were completely overhanging the adjacent young seedlings. Owusu and Ollennu (1997) observed in a re-infection trial that the first incidence of infection in the young replanted cocoa occurred where old infected trees overhung or were in contact with young trees in the adjoining two or three rows. It is therefore not surprising that a young cocoa tree was found visibly infected in one of the farms visited and a seedling from another farm under similar circumstances was also found infected after indexing (Table 2). The finding that one seedling in each farm was already infected may seem insignificant in number, but certainly has serious consequences for the future of these farms. This is because further spread is inevitable from the initial source of infection once the seedlings develop additional leaves and shoots to support populations of the mealybug vector and the branches form as interlocking canopy of branches that facilitate their movement form tree-to-tree as described by Strickland (1951) and Cornwell (1960). All favourable factors influencing spread then come into play and rapid spread occurs. Another well-known source of re-infection is the old cocoa left within the young ones. For example in an attempt to control swollen shoot in the replanted farms established in the Eastern Region cocoa rehabilitation project, 76% of the 64,803 infected trees removed were old cocoa trees left amongst the new plantings (Owusu and Ollennu, 1997). Yet, as was observed in the survey reported here, old cocoa is still being left in the midst of young ones thus facilitating early infection of the newly planted cocoa.

The fact that no visible infection was found in the adjoining old cocoa trees in the Volta Region is not very surprising because of the sparse distribution of cocoa in the region, and the reported success of earlier phases of the eradication campaign in the Region (Kenten and Legg, 1971), which resulted in a significant reduction in the inoculum level.

In an attempt to deal with re-infections encountered in the earlier phases of the eradication campaign, a cordon of 10 m was recommended between newly established farms and adjacent old cocoa around the boundaries. This recommendation was based on experience in Nigeria (Are, 1969). In recommending this procedure for use in Ghana, Ollennu et al. (1989a) added that the 10 m cordon should be planted with a CSSV-immune crop to provide separation and form a physical barrier to the movement of mealybug vectors. They further reported that removal of all known infected trees from the adjoining area before replanting prevented CSSV re-infection, confirming an earlier observation in Ghana by Ampofo and Osei-Bonsu (1988). This recommendation, however, is difficult to implement because of the reluctance of Ghanaian farmers to leave such areas of land unplanted, which in some cases end up taking all their parcel of land especially when the plot is small and convoluted with a high perimeter/area ratio. Recent studies have evaluated the immunity and effectiveness of some economic crops as barriers for planting in these cordons. Two such crops, citrus and oil palm showed much promise as good barriers to CSSV re-infection into younger cocoa (Ollennu et al., 2002) and their economic returns have been shown to be comparable to cocoa. How to promote these findings to the risk-averse Ghanaian cocoa farmer, who wants cocoa at all costs, remains a challenge to researchers and policy-makers. It is a challenge that could be overcome by adopting appropriate communication and extension strategies to modify farmers' attitudes towards the recommendation. The chances of a favourable response would be boosted by farmer-involved demonstrations of the benefit of including the barrier crops in farmers' cropping systems.

Another alternative is to plant cocoa in large blocks and to either isolate the block with barriers of immune crops or provide no barrier but regularly inspect and treat all adjoining old cocoa around the boundaries. The usefulness of block planting has been demonstrated clearly in the delay of re-infection for many years even in the most susceptible Amelonado cocoa planted in blocks in some parts of the Eastern Region (Benstead, 1951). These farms were however not sufficiently separated from older cocoa around their boundaries and the eventual source of re-infection was invariably from these adjoining cocoa trees. Block plantings with surrounding unplanted areas or cordons of immune crops will therefore provide the best opportunity to rehabilitate farms destroyed by CSSV in the endemic areas.

However, the current land tenure system in some of the CSSV-endemic areas in Ghana precludes block plantings, and it has been suggested that neighbouring farmers should be encouraged to pool their individual small land holdings and other resources to grow large blocks (Owusu and Ollennu, 1997). This recommendation is crucial as the unsatisfactory experience from the small farms replanted under the ‘‘plant-as-you-cut’’ scheme has shown that this is not advisable. A survey by Legg and Owusu (1976) of such farms showed that just 3 years after replanting, about 1% of young cocoa had become infected and this led Thresh et al. (1988b) to suggest that replanting areas of less than 0.4 ha should be discouraged.

Another possibility to solve the land tenure problem and to make large parcels of land available for cocoa is for the central government to facilitate the setting up of land banks into which individuals, families and other land-owners could be encouraged to pledge their lands to be used for specific projects, which may include rehabilitation of farms destroyed by CSSV.

In the absence of large tracts of land to provide adequate isolation of replanted farms or for planting in blocks, breeding for disease resistance/tolerance has also been advocated as another way of CSSD management (Owusu, 1983; Thresh et al., 1988a, b; Ollennu et al., 1989a, b; Owusu and Ollennu, 1997) and this is now being vigorously pursued at CRIG. Breeding by selecting both parents for CSSV resistance is now the agenda. Indeed, Posnette (1981a) stated that breeding for resistance to CSSV that can reduce the spread of the virus by about 20% will be most desirable and can go far to solve the swollen shoot disease problem.

Although the observations in the field and the results of the indexing experiment conducted here back the assertion that alternative host plant may no longer be important source of re-infection into cocoa as compared to cocoa-to-cocoa transmission (Posnette, 1981b), the presence of *C. gigantea,* in the midst of newly planted cocoa farms can still be worrying and it is prudent that such trees should be removed.

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