Chapter

Management of the Cacao Swollen Shoot Virus (CSSV) Menace in Ghana: The Past, Present and the Future

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Abstract

This chapter outlines and discusses some of the challenges associated with management of the cacao swollen shoot virus (CSSV) disease in Ghana and its impact on cocoa production. The discussion will bring to the fore some of the factors that has militated against implementation of the recommended management strategies in the past and its consequential effect on the present widespread of the disease across the various cocoa regions in West Africa. The wide variability in the different strains of the virus as manifested in recent molecular studies is highlighted as a possible contributor and explanation for the prevalence and varying virulence of the disease in new infections, especially, in the Western region of Ghana. Current research efforts and strategies aimed at minimizing of CSSV continuous spread and devastation on Ghana's cocoa production is discussed.

Keywords: cocoa, swollen shoot virus disease, mealybug vector, CSSVD

1. Introduction

The cocoa industry plays critical role in the socioeconomic development of Ghana by providing employment and source of livelihood to many farm families and other stakeholders in the cocoa value chain. Export of cocoa beans and other cocoa products is a major avenue for the generation of the much needed foreign exchange for the economies of Ghana and Cote d'Ivoire. Sustainability of the cocoa industry is therefore critical for the governments and people of these West African nations and other stakeholders in the cocoa business. Cocoa cultivation is however bedeviled with several production problems as the cocoa plant is affected by numerous diseases and pests which accounts for significant yield losses in the various cocoa producing nations across the world (**Tables 1** and **2**). Five major diseases of the cocoa plant (*Theobroma cacao* L.) namely; *Phytophthora* pod rot (black pod), witches broom, cacao swollen shoot virus, vascular streak dieback, and monilia pod rot account for over 40% annual yield loss across the different production regions [1].

The cacao swollen shoot virus disease (CSSVD) which is considered the most economically important cocoa virus disease could account for 15–50% yield loss if the severe strains are involved in infections [2, 3]. Since the discovery of this important disease in Ghana, it has been managed through the "cutting out and replanting

Type of pathogen	Disease (common name)	Causal pathogen
Oomycete	Black pod	*Phytophthora palmivora*
Oomycete	Black pod	*Phytophthora capsici*
Oomycete	Black pod	*Phytophthora citrophthora*
Oomycete	Black pod	*Phytophthora heveae*
Oomycete	Black pod	*Phytophthora megakarya*
Fungus	Black rot	*Rosellinia bunodes*
Fungus	Black rot	*Rosellinia pepo*
Fungus	Black thread	*Marasmius scandens*
Oomycete	Canker	*Phytophthora palmivora*
Oomycete	Canker	*Phytophthora megakarya*
Oomycete	Canker	*Phytophthora citrophthora*
Fungus	Charcoal pod rot	*Lasiodiplodia theobromae,*
Fungus	Cushion gall	*Colonectra rigidiuscula*
Fungus	Frosty pod	*Moniliophthora roreri*
Fungus	Mealy pod	*Trachysphaera fructigena*
Fungus	Pink disease	*Corticium salmonicolor*
Fungus	Root rot	*Phellinus noxius*
Fungus	Thread blight	*Marasmius scandens*
Fungus	Warty pod	*Trachysphaera fructigena*
Fungus	White thread	*Marasmiu sequicrinis*
Fungus	Witches' broom	*Moniliophthora perniciosa*
Fungus	Witches' broom	*Moniliophthora crinipellis*
Viruses	Cacao swollen shoot virus disease	*Cacao swollen shoot virus* (CSSV)
Viruses	Cacao yellow mosaic virus	*Cacao yellow mosaic virus (*CYMV)
Viruses	Cacao necrosis virus	*Cacao necrosis nepovirus (*CNV*)*

Table 1.
Causal pathogens of common cocoa diseases in the world. Source: [48].

system" with the aim of removing sources of inoculum from affected cocoa plantations and replanting with tolerant cocoa hybrids [3–5]. Nonetheless, reports from many reassessments and disease surveys indicate that the prevalence of the disease is still high with varying virulence across the cocoa regions. This has partly been attributed to the poor implementation of the cutting out program to manage the disease. This chapter highlights some of the past challenges that have bedeviled the "cutting out system" and discusses some of the current strategies being implemented by the various stakeholders and researchers to minimize the continuous spread and impact of the disease on cocoa production in Ghana and Cote d'Ivoire.

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Diseases	Pathogen	Region	Estimated reduction in production and income	
			(tons x 1000)	($ millions)
Black Pod	*Phytophthora* spp.	Africa/Brazil/Asia	450	423
Witches' Broom	*Crinipellis perniciosa*	Latin America	250	235
Cocoa Swollen Shoot Virus Disease	CSSV	Africa	50	47
Frosty Pod Rot	*Moniliophthora roreri*	Latin America	30	28
Vascular-streak dieback	*Oncobasidium theobromae*	Asia	30	28

Table 2.
Economic losses from some important cocoa diseases across the world. Source: [48].

2. The cacao swollen shoot virus disease (CSSVD)

The *Cacao swollen shoot virus* disease (CSSVD) was first noted in the Eastern Region of Ghana in 1936 by a farmer in a form of cocoa stem swollen conditions [6] but its virus nature was confirmed in 1939 [7]. The disease is considered the most important cocoa viruses in West Africa due to its devastating effect on yield and possibility of causing death of cocoa plants especially when the severe strains are involved in infections [8, 9]. The virus affects all parts of the cocoa plant and the severe strains induce varying leaf symptoms and swellings of the stems and roots. Some of the leaf symptoms include; red vein banding of the immature "flush" leaves [10] (**Figure 1**); chlorotic vein flecking or banding which may occur in angular flecks (**Figure 2**). Stem swellings occur at the nodes, internodes or tips of the stem [2, 10], (**Figures 3** and **4**).

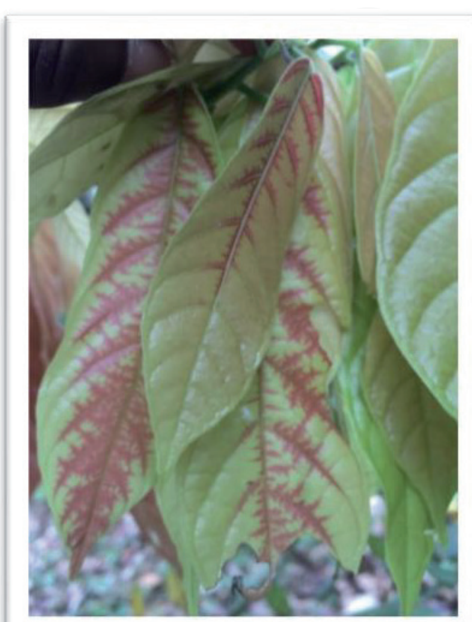

Figure 1.
Red vein banding.

Figure 2.
Chlorotic vein banding.

Some strains also cause infected pods to change shape and become rounder, smaller and with smoother surfaces [11].CSSV is classified as a member of the plant-infecting pararetroviruses in the genus badnaviridae which are with non-enveloped bacilliform particles that encapsulate a circular double stranded DNA-genome [12–15]. The viral particle of CSSV is identified with length measurements in the range of 121–130 and a width of 28 nm [12]. The genome size ranges from 7.4 to 8.0 kilobase pair depending on strain [16, 17]. The CSSV genome is organized into five putative open reading frames (ORFs 1, 2, 3 X and Y) located on the plus strand of the 7.16 kbp [15].

2.1 CSSVD isolates and strains

Generally, isolates of the virus have been designated by naming them according to the nearest town or village where they are first collected and are generally

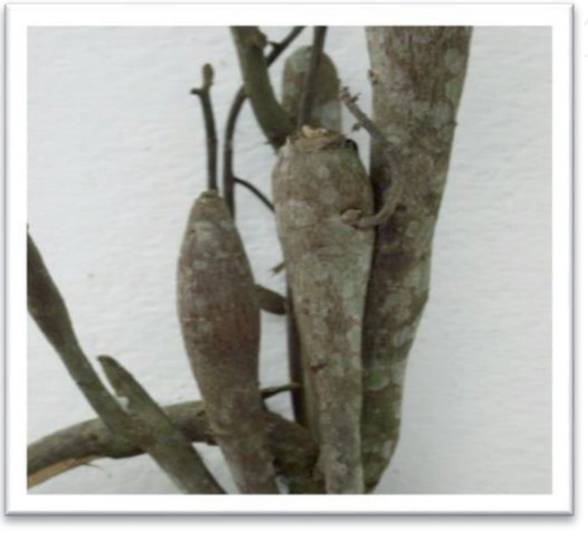

Figure 3.
Tip swelling.

Figure 4.
Shoot swelling.

grouped according to severity of symptom expression and geographical origin [12–15]. Ghanaian CSSVD isolates are distinguished five groups of through enzyme linked immunosorbent assay (ELISA) and immunosorbent electron microscopy (ISEM) techniques and by using leaf symptoms [18]. Recent molecular studies with the use of advance sequencing methods such Next generation tools have provided the opportunity to further classify CSSV isolates across the West African sub-region into new groups based on their molecular information at the DNA level. Some of these studies have identified wide variability in the strains of the virus and virulence of the disease in new infections especially in the Western region of Ghana [3, 19, 20]. The strains of the virus have now been reclassified based on their molecular diversity into groups A, B, C, D, E, F, G, H, G, J, K. L, M, and N [**Figure 5**].

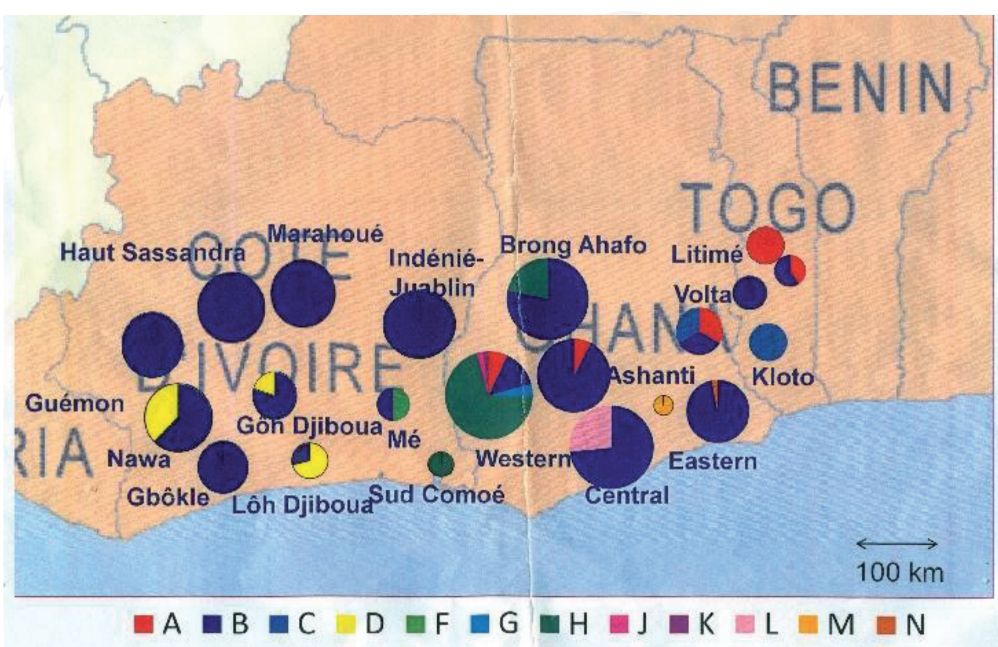

Figure 5.
Molecular diversity of CSSV in West Africa [47].

2.2 CSSVD transmission

CSSV is semi-persistently transmitted by several species of mealybugs (*Pseudococcidae*, *Homoptera*) on cocoa [21, 22]. The vectors feed on all parts of the cocoa tree including flowers, cherelles, pods and leaves. The mealybug species differ in their ability to transmit different strains of the virus. The most efficient mealybug transmitters of the virus include the *Planococcoides njalensis* (Laing), *Planococcus citri* (Rossi) and *Ferrisia virgata* (Okll) specie which are also dominant on cocoa fields in Ghana and Cote d'Ivoire (**Figure 6**). The ages of the mealybugs are also important in the spread of the virus in that only the young adults (nymphs) are very mobile and so are more efficient transmitters than the adults which are most often sedentary [23]. The use of mechanical inoculation procedures to transmit CSSV was made possible in 1960 [24]. Considering the continual spread of the virus to new cocoa plantings, research is still focusing on other insect pests in the cocoa environment to ascertain their vector status regarding CSSV transmission in the field.

2.3 CSSVD alternative hosts

The virus is considered to have originated from wild indigenous forest trees within the cocoa environment [25–28]. This suggestion was based on studies in the Western Region of Ghana which showed that some of the CSSV isolates could be found in some forest trees such as *Cola chlamydantha* (K. Schum), trees and the prevalence of the disease was also high in areas where these trees were found. Other tree species that have subsequently been identified as wild alternative hosts of CSSV include *Erythropsis barteri* (Mast), *Sterculia tragacantha* (Lindle), *Sterculia rhinopetala* (K. Schum), *Cola gigantean* var. *glabrescens* (BronnanetKeay), *Adansonia digitata* (L.), *Bombax buonopozense*, and *Ceiba pentandra* (L.), [25]. It is, however, noteworthy to indicate that not all the wild hosts are good sources of the virus and also its availability declines to a low level in the bigger and old trees which sometimes makes the virus not readily available to the mealybug vectors. Mechanically transmission CSSV from some of the wild hosts to cocoa and vice versa was achieved in 1962 [24]. It was therefore recommended that the abovementioned forest trees known to be alternative host plants for the virus be removed as much as possible from cocoa plantations before replanting with new cocoa to prevent early

Figure 6.
Mealybug infested cocoa pods.

reinfection [29]. Currently, research is focusing on other possible alternative host plants of CSSV in the forms of weeds and food crops within the cocoa ecosystem.

2.4 CSSVD spread in the field

Generally, the spread of the virus in the field is triggered by several factors such as the size of the initial source of infection, and the age and type of the mealybug population present [8, 9, 29]. Apparently, natural spread of the virus is slow under low inoculum pressure (i.e., presence of few inoculums sources) because it is dependent on the movement of the mealybug vectors infected with the virus. It is also slow within young plantings until the trees become well established and form a continuous canopy of interlocking branches [29]. Nevertheless, virus infected mealybugs are occasionally blown by wind to uninfected trees some distance from the original site of infection resulting in jump spread of the virus to uninfected areas to initiate new outbreaks [30, 31]. New outbreaks of CSSV tended to be concentrated around the periphery of existing outbreaks (infections) or abandoned forests with alternative hosts which then spread slowly to give clearly defined expanding foci [29]. The pattern of spread within outbreaks was noted to be of a circumscribed nature and tended to be high close to source of infection. Existing outbreaks then initiates new "satellite" outbreaks through "jump" spread over wider distance by windblown mealybugs. These new "satellite" outbreaks enlarge and eventually coalesce to form large areas of mass infection. Spread of the disease within outbreaks was however noted to result from movement of mealybugs carrying the virus from infected to healthy trees. It was noted that new outbreaks get bigger close to large sources of infection and diminish further away from them [32].

3. CSSVD control strategies

Management of CSSVD in Ghana has over the years been carried out in an integrated manner involving the use of different strategies such; as the cutting out method, mealybug control, removal of alternative hosts, and the use of tolerant planting materials. These control strategies and some of their challenges are discussed below.

3.1 The cutting out method

Cutting-out of CSSVD infected cocoa trees together with a ring of nearby apparently healthy cocoa trees have been the main method adopted to control the spread of the virus in Ghana since 1946. The aim of this strategy is to eliminate or reduce the sources of infection (inoculums) within new cocoa plantings. Once the infected cocoa trees are removed, the field is expected to be replanted with CSSVD tolerant cocoa varieties from the seed gardens. This method has gone through several challenges in its implementation thereby resulting in the continuous spread of the virus to new areas [5, 9]. Although most of these challenges are intertwined, notable among them include; late discovery of infections, lack of continuity of the program, non-co-operation of farmers due to issues of compensation payments, land tenure issues, and non-adherence to replanting recommendations after the removal of sources of infection [5, 8, 29].

3.1.1 Late discovery of infections

The effectiveness of the cutting out procedure depends largely on the efficiency of early detection of infections [9]. The disease identification system whereby trained diseased spotters carry out tree-by-tree inspection for visual symptoms of the virus inevitably means that latently infected trees which have not produced symptoms at the time of inspection are missed. Considering the pattern of CSSVD spread [29] which is mainly limited to adjacent trees around the periphery of existing outbreaks, it can be argued that, the disease spotters follow the virus and are always "one step behind". It is also generally known that CSSVD symptoms tend to be least conspicuous during the dry season when the trees deteriorate and leaves and shoots are shed or damaged by capsids [9]. Considering the common phenomenon of dehydration and less active growth of infected trees during the dry season, it is very likely that disease spotters would miss some infected trees in the field during these periods. There is thus a high possibility that these missed infections could be supporting mealybug population and also transmit the disease even though they may not show conspicuous symptoms [8, 9, 23]. The challenge of lack of efficient detection protocol for the virus at the early stages has therefore generally been considered among the reasons why the disease continues to spread at an increasing rate in Ghana. The need for efficient early detection tools has always been advocated to be one of the means to help in the effective management of the virus.

3.1.2 Lack of continuity of the cutting out program

National implementation of the cutting out program has been delayed or halted on many occasions for numerous reasons such as; farmer opposition, logistical constraints, lack of funding, and at times political interference [5]. Although, it is known that continuity in the cutting out operation would have been very essential for the control of other viral diseases in other areas it has never been achieved most especially in Ghana. There is always time lag between symptom identification in outbreaks and time to treatment and replanting.

3.1.3 Non-adherence to replanting recommendations

Replanting of treated cocoa farms according to laid down recommendations could have been successful in rehabilitating devastated cocoa areas. However, it was noted that newly planted farms in most of the cocoa areas, especially, in the Western Region, showed symptoms of re-infection with the virus [4]. This is because farms are replanted very close to the boundary of abandoned cocoa farms containing visible infections, without much attempt to remove the infected trees in the old plantations. The recommendation that replanting should only occur after the complete removal of sources of infected cocoa trees or alternative host plants, have not been applied adequately in the eradication and replanting exercise hence contributing to the prevalence of the disease across cocoa farms.

3.1.4 Presence of alternative hosts in newly replanted farms

The occurrence of wild alternative host plants of the virus in and around cocoa farms is a contributory factor to spread and early re-infection of new cocoa plantings in Ghana [25]. Even though, removal of wild alternative host trees has been recommended, it is seldom applied. The advice to farmers to leave at least a 15 m barrier with some economic crops such as citrus and oil palm around new cocoa plantings to delay reinfection from old plantations and forest trees have also not been implemented fully. Farmers always want to fully utilize all available space of land for cocoa planting and also use the alternative host trees as a source of natural shade for their cocoa during the early growth period.

3.1.5 Lack of effective control methods for mealybugs

The use of synthetic chemicals for the control of the mealybug vectors has not been effective over the years. This is attributed to the morphology of the mealybugs having a protective wax covering and also the building of mud tents over them by black ants [33–36]. Attempts by scientists with the use of biological means have also not been successful [37].

3.1.6 Use of resistant cocoa varieties

Even though it has long be envisaged that planting of cocoa varieties tolerant to CSSVD would be the most effective means to manage the disease [38], most of the available cocoa planting materials has however shown low levels of resistance under field conditions. It is notable that many of the inter-Amazon hybrids developed and recommended by the British Research Team and currently available to farmers [38] have only partial resistance to CSSVD [38–40]. Although partial resistance is beneficial for being able to tolerate the virus to give appreciable yield in the short to medium term, the need for varieties that could offer greater resistance cannot be overemphasized. The continuous search for varieties that could offer long-term resistance that has been going on over the years using modern breeding approaches such as mutation and tissue culture techniques in Ghana and elsewhere is therefore very appropriate [41].

3.1.7 Mild strains cross protection

Long term field assessment of the mild strain cross protection experiments carried out at the Cocoa Research Institute of Ghana (CRIG) has shown that, the immunity conferred on the healthy cocoa plants from the available mild strains N1 and SS365B eventually breaks down after 20 years [42, 43]. These reports support past works and suggestions that further investigations on the effectiveness of the mild strain phenomenon need to be carried out before its adoption as a management strategy for the virus [44–46].

4. Current strategies on CSSVD management

The cutting out and rehabilitation program was re-launched in June 2018 to concurrently cut out CSSVD infected cocoa trees along the borders of Ghana and Cote d'Ivoire. The expectation is to progressively remove about 100,000 ha of infected CSSVD outbreaks across the cocoa regions in Ghana by 2023. The current cutting out activities involves the total removal of CSSVD infected cocoa trees in blocks of outbreaks and replanting with tolerant cocoa varieties. Payment of compensation to farmers and land owners has been incorporated into the program to sustain farmers' livelihood during the periods of cocoa tree removal and replanting. Additionally, farmers would be supported in their cocoa farm establishment and maintenance activities such as provision of temporary and permanent shade plants, farm weeding and fertilizer application. Cutting out activities are to be intensified in high prevalent areas such as the Western and Eastern regions of Ghana.

Scientific research activities to support the program have been strengthened to include development of early detection tools, mealybug vectors control, identification of other alternative hosts and vectors as well as development of resistant cocoa varieties. Characterization of the diversity and virulence of the disease across the West African Sub-region is also to progress to understand the nature of the virus at the molecular level. Diversity studies to classify the virus into distinct groups of strains and isolates as identified in the Western region and adjoining areas of the Brong Ahafo Region is also being aggressively pursued to explain the difference in virulence and symptoms of the disease in different outbreaks.

5. Conclusion

The cutting out approach to remove sources of infection from farms still remains the most feasible method to manage the spread of CSSVD in an integrated system with other agronomic practices. Emphasis should therefore be placed on finding the most logical and efficient means of carrying out the program with the support of farmers and other relevant stakeholders. Accordingly, extensive farmer education on the effects of the disease and the rationale behind removal of sources of infection from outbreak areas is very imperative. Additionally, policies and rate of treatment and replanting needs careful coordination both at the District and Regional levels and this should take into consideration the severity of the disease and the availability of adequate manpower and resources to implement the program according to laid down recommendations.

The ineffectiveness of the cutting out strategy as noted in the past should be placed in the appropriate context of the many problems or challenges in its implementation together with the logistical and manpower constraints that have characterized the cutting out scheme from the outset. This chapter highlighted some of the challenges of the cutting out system and still recommends its application in an integrated approach involving the use of different measures in a coordinated manner. The focus for current and future scientific research and topics for consideration include; the use of modern breeding techniques to develop resistant cocoa varieties for CSSV, studies on chemical and biological control of the mealybug vectors, development of early detection tools, and identification of other vectors and hosts of the virus.

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