Effect of Proper Management of Cocoa Plants on the Occurrence of Swollen Shoot Disease in Kipiri - Côte d'Ivoire

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Authors’ contributions

This work was carried out in collaboration among all authors. Author FZO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HDL and JK managed the analyses of the study. Author CAN managed the literature searches. Authors LD and CK designed the study and approved final protocol. Author HAD was the principal investigator. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to evaluate the relationship between plot maintenance level and the prevalence of Cocoa swollen shoot disease in Kipiri (Department of Soubré) in Côte d’Ivoire. Indeed, the strong pressure of Swollen shoot disease in this department causes enormous damage in cocoa plots. The study design is a prospective survey in peasant cocoa plots between 2014 and 2016. The data were collected using the Land Degradation Surface Framework (LDSF). The LDSF device

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is a sentinel site of 10 Km × 10 Km. The site is divided into 16 Clusters of 2.5 Km × 2.5 Km with 10 plots by cluster. In the case of our study, surveys were carried out on 108 plots carrying cocoa trees within a radius of 50 m around each test plot. The data collected included areas of *Cocoa Swollen Shoot Virus* (CSSV) outbreaks, the cocoa plot maintenance level and CSSV status like ‘Absence’ or ‘Presence’ in plots observed. CSSV prevalence was deduced from CSSV outbreaks areas of each sampling plot, allowing realization of disease map. The relationship between the level of plot maintenance and the prevalence of CSSV was assessed by using the analysis of variance test (ANOVA-one-way).

The results of Swollen shoot disease’s distribution showed that the Kipiri site had a CSSV prevalence around 50%. These results demonstrated that plots maintenance level has a strong influence on the prevalence of Swollen shoot disease ($p = 0.00 < 0.05$).

At the end of this study, it appears that plots maintenance level is a key factor in the rapid spread of the Swollen shoot epidemic in Kipiri site. Cocoa producers would therefore be recommended to regularly maintain their plantations by eliminating the reservoirs of *Cocoa Swollen Shoot Virus*.

Keywords: CSSV; cocoa; plot maintenance; Soubré; Côte d’Ivoire.

1. INTRODUCTION

Côte d’Ivoire is a West African country whose economy is based on the agricultural sector. Ivorian agriculture is dominated by cocoa cultivation, which is the main agricultural activity of the country [1]. Cocoa production in Côte d’Ivoire is about 1.50 million tons / year of cocoa beans, making country the first producer in the world with 35.6% of market share [2]. Cocoa provides significant economic support Côte d’Ivoire state with 15% of the Gross Domestic Progress (GDP) and 30% of export earnings [3]. However, cocoa growing in Côte d’Ivoire is increasingly facing various constraints, such as the aging of cocoa plots, the instability of cocoa buying prices, the attacks of mirids, black pod disease and especially Swollen shoot disease [4]. Indeed, since year 2003, the Swollen shoot disease spreads quickly in the Ivorian cocoa plots [5]. Swollen shoot is a viral disease that causes inestimable losses to producers, where many millions of plants are destroyed each year [6]. *Cocoa Swollen Shoot Virus* (CSSV) is an endemic disease transmitted by mealybugs from Pseudococcidae family [7]. Historically, CSSV was discovered for the first time in Ghana in 1936 and was also observed in other West African countries such as Togo, Nigeria, Liberia and Sierra Leone [8]. In Côte d’Ivoire, the Swollen shoot was observed for the first time in 1946 in the departments of Abengourou and Agnibilékro [9] located in south eastern. In 2003, a survey revealed new outbreaks in central West of Côte d’Ivoire, specifically in Sinfray department, Issia and Bouaflé departments [10]. Thus, in 2008, the Coffee and Cocoa Council launches the national project to fight against Swollen shoot disease.

![Symptoms of Swollen shoot disease](image)

**Fig. 1.** Symptoms of Swollen shoot disease: (A): intense red coloration along the secondary veins and limb on young leaves, (B): swelling of stems
disease in Côte d'Ivoire [11]. The evaluation of the impact of CSSV in Côte d'Ivoire allowed to detect new virus isolates in the new cocoa production areas [12]. However, new outbreaks have recently been identified in the region of Soubré which is now a high cocoa production area [13]. The typical symptoms (Fig. 1) of this disease are recognizable by redness on the veins of young leaves and swelling of young stems [14]. The infected plant gradually loses its leaves and dies after three to five years [15]. CSSV is spread gradually by outbreaks [15]. The only method to manage this disease are to uproot infected areas [5]. Despite this, the disease is spreading more and more across all cocoa growing areas. This rapid spread could be linked to factors relating to cultural practice, including the maintenance of plots, as reported by Oro and his collaborators in the case of black pod disease in 2019 [16]. In addition, very few studies have been carried out in Côte d'Ivoire to identify these factors responsible for the development of this disease. Moreover, there is no information database on disease prevalence in order to inform decision-makers and research structures in developing effective methods to reduce disease spread. These are the reasons that motivate this study. The present study aims to evaluate the influence of maintenance level of cocoa plots on the prevalence of Swollen shoot disease in Kipiri, southwestern Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Soubré department, located in the south-west of Côte d'Ivoire. This department produces most of the cocoa stocks of Côte d'Ivoire (Fig. 2). The observation surveys were carried out on the Kipiri site (6 ° 29' W and 6 ° 8' N) which is one of the sites previously prospected as part of the implementation of the Vision for Change (V4C) project, piloted by World Agroforestry Center (ICRAF) of Côte d'Ivoire.

Fig. 2. Map of the Nawa region showing Kipiri site [13]
2.2 Experimental Design

The surveys were conducted according to the LDSF (Land Degradation Surveillance Framework) protocol. The LDSF was developed by ICRAF Nairobi researchers to monitor agriculture-friendly soils throughout West Africa [13]. This protocol has been adapted for epidemiological investigations of Swollen shoot disease. The LDSF device is a sentinel site of 10 Km × 10 Km. The site is divided into 16 Clusters of 2.5 Km × 2.5 Km (Fig. 3). Each site has 160 observation points, called plots. In the case of our study, surveys were carried out on the 108 plots carrying cocoa trees.

2.3 Data Collection

Data collected relate to Swollen shoot outbreaks area, cocoa trees coverage of plot and the plot maintenance level.

2.3.1 CSSV outbreak area

CSSV data collection was carried out at each observation plot level, previously identified using a Global Position System (GPS). Around the plot, an observation area of 50 m radius has been defined (Fig. 4). In this observation area, CSSV outbreak were detected on the basis of several indicators including clearings, symptoms on the leaves (redness along the veins), symptoms on the stems (swelling) and symptoms on pods (stunting). In each observation area, several CSSV outbreak can be detected in case of presence. In each CSSV outbreak, the areas were measured using a Garmin GPS and the center coordinates of CSSV outbreak were recorded. The areas of CSSV outbreak will be used to determine the prevalence of CSSV. This prevalence is calculated from the ratio of CSSV area to the total observation area (7850 m²). Then, a previously prepared survey sheet is filled in to form physical data.

2.3.2 Cocoa trees coverage rate and CSSV prevalence

The cocoa trees coverage rate is relative to the area effectively covered by cocoa trees in the sampled plot. It was determined on the basis of general observation of the sampled plot. Thus, one could have 0,1 to 1 coverage rate. The prevalence of Swollen shoot disease has been adjusted from the coverage rate according to the formula:

\[ P = \frac{SF \times TC}{SP} \times 100 \]

\[ P = CSSV \text{ Prevalence} \]
\[ SF : CSSV \text{ outbreak area} \]
\[ TC : \text{Cocoa trees coverage rate} \]
\[ SP : \text{Cacoa plot area} \]
2.3.3 Plot maintenance level

The plot maintenance level was determined by general observation of the plot. When the plot is maintained, it is coded as one (1), and if it is unmaintained, it is coded zero (0). The unmaintained plots are characterized by a very high level of grass and a lack of cocoa regrowth, unlike the plot maintained.

2.4 Data Analysis

Data analysis included CSSV distribution map, descriptive data analysis, and comparative data analysis. The statistical analysis of the data was performed using the IBM SPSS statistics 20.0 software.

2.4.1 CSSV distribution map

The distribution map was made with geographical coordinates of each observation plots and CSSV status like presence or absence. This map has been realized with SPSS software. It is from this map that the rate of presence of the disease (TX) was calculated, by taking the ratio of the infected plots (X) with respect to all the observation plots (Y), according to the formula:

\[ TX = \frac{X}{Y} \times 100 \]

2.4.2 Descriptive analysis of the data

The descriptive analysis consisted of describing variables such as the prevalence of Swollen shoot, the plots maintenance level and CSSV status of the plots. The total area of outbreaks and the prevalence of Swollen shoot disease being quantitative variables characterized by mean, minimum, maximum, and standard deviation. These parameters were determined to understand their dispersion throughout the study site. The qualitative variables that are the plots maintenance level and the status of the plot were represented by their size and the corresponding frequencies in a table.

2.4.3 Comparative analysis of data

Comparative analysis of the data made it possible to evaluate statistically the influence of plots maintenance level on Swollen shoot disease prevalence by performing a one-way ANOVA (variance analysis).

3. RESULTS AND DISCUSSION

3.1 Distribution Map and Prevalence of CSSV

The analysis of CSSV map distribution showed that on the Kipiri site, 83 plots are infected on 108 plots contained in this site (Fig. 5). This represents an incidence of 77%. The results of Swollen shoot disease’s distribution showed that the Kipiri site had a CSSV prevalence around 50%. This result is in agreement with that obtained by Diby and his collaborators in 2014 [13] which stipulated that Kipiri site was one of the sites which is affected by Swollen shoot disease with a prevalence of 48%. This confirms that the disease is progressing in the cocoa plantations of Soubré [15]. This progression could be linked to the failure to manage the disease on a national scale. Indeed, methods of
uprooting infected trees are difficult for producers to adopt because they destroy large areas of cocoa trees [1-6].

3.2 Effect of Plot Maintenance Level on CSSV Prevalence

The descriptive analysis (Table 1) shows that the average area of outbreaks observed at the Kipiri site is 4291 ± 3299 m². Totally degraded plots have a prevalence of 100% and healthy plots 0%. The average prevalence at Kipiri site was 50.4 ± 40.9%. The descriptive analysis of the qualitative variables such as plot maintenance level and CSSV status of plots indicates that in Kipiri, very few plots are maintained (25%). This justifies a strong prevalence (Tables 2 and 3) of Swollen shoot disease (76.85%).

The comparative analysis of CSSV prevalence and plot maintenance level showed that the unmaintained plots have a prevalence ranging from 10% to 100% with a median around 60%. This reflects that the majority of unmaintained plots have a high prevalence of CSSV. On the other hand, the maintained plots have relatively low prevalence which varies between 0% and 60%. However, many maintained plots have a low prevalence of less than 10% (Fig. 5). The Anova test result showed a significant difference ($P = 0.026$) between the Swollen shoot prevalence and plot maintenance level (Table 4). This leads that plot maintenance level is linked to high spread of Cocoa swollen shoot disease in Kipiri.

The results of this study also showed that the level of maintenance of the plots was significantly linked to the prevalence of Swollen shoot disease at the Kipiri site. This close relationship between the CSSV prevalence and plot maintenance level is linked to the high proportion of unmaintained plots whose median prevalence rates are higher (60%) than those of maintained plots (20%). In fact, the unmaintained plots are those in which there is a high rate of grassing, thus creating nests of proliferation of mealybugs that transmit CSSV disease [17]. These grassing conditions create sources of infection by favoring contamination from one tree to another [15]. These results are in agreement with those obtained by Gidoin [18] in Cameroon who showed that an unmaintained cocoa plantation facilitates the spread of insect pests and mealybugs. These insects could be the source of propagation of the pathogen [11].
Fig. 6. Boxplots of Cocoa Swollen shoot virus prevalence according to plots maintenance level

Table I. Descriptive statistics of plot maintenance level parameters

| Plot maintained level | Numbers | Percentage (%) |
|-----------------------|---------|----------------|
| Unmaintained plots    | 81      | 75.0           |
| Maintained plots      | 27      | 25.0           |
| Total                 | 108     | 100            |

Table 3. Descriptive statistics related to cocoa swollen shoot virus status of sampled plots

| CSSV Status | Numbers | Percentage (%) |
|-------------|---------|----------------|
| Absence     | 25      | 23.2           |
| Presence    | 83      | 76.9           |
| Total       | 108     | 100            |

Table 4. Anova test result

|                        | Sum of squares | df | Mean Square | F   | Sig.   |
|------------------------|----------------|----|-------------|-----|--------|
| Between Groups         | 8198.2         | 1  | 8198.2      | 5.1 | 0.026  |
| Within Groups          | 170566         | 106| 1609.1      |     |        |
| Total                  | 178764         | 107|             |     |        |

4. CONCLUSION

At the end of this study, it appears that Swollen shoot disease is actively spreading on the Kipiri site with a prevalence of 50%. This progression could be linked that disease management techniques which are poorly adopted by cocoa producers. In addition, this study showed that the progression of the disease on this site is strongly dependent on the non-maintenance of the plots. Indeed, the level of grass in the plot could be a potential reservoir of mealybugs vector of the Swollen shoot disease. To this end, producers would be recommended to maintain their plantations regularly by eliminating weeds and cocoa trees already showing visible symptoms so as to limit the rapid spread of the disease.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
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