11
Spatial and Temporal Mapping of CWD

11.1 Main Findings

- The spread of coffee wilt disease (CWD) through observation Robusta plots was studied in Uganda.
- Initial infection of individual coffee trees was essentially random, and there was no indication of how it arrived in the plot.
- There was no clear indication of a general spread of infection across fields, which might be expected if the disease was water- or wind-borne.
- There was evidence, however, that once established in a plot, the subsequent spread of infection is from a tree to its neighbouring tree, since the disease gradually spreads outwards from initial foci of single-tree infections.
- The means of this spread is still unknown, but most likely involves transmission through the soil.
- Statistical analysis suggests that an infected tree can cause infection to trees up to 10 m distance, i.e. three rows away. Hence, the eradication of isolated trees in a healthy plot should also include the neighbouring trees to stand a good chance of halting an infection.

11.2 Introduction

Chapter 10 studied how CWD can be spread on infected implements, coffee wood and soil. But we need to know more about how it spreads through a coffee field, in order that we could slow its advance and advise more accurately on preventative measures, for example the minimum number of trees to destroy in the vicinity of an infected tree.

11.3 Study Sites

The development of CWD infection at a number of selected field sites at Coffee Research Institute (CORI) and coffee farms in Mayuge and Iganga districts (Eastern Uganda) and Masaka and Rakai districts (Central Uganda) was closely monitored by CORI staff since 2002. Visits were made to each site at 1- or 2-month intervals, and the incidence and severity of CWD on selected coffee trees within a demarcated area were recorded. The objective of this work was to use the data so obtained to generate disease distribution maps to help determine the rate and manner in which CWD spread at these sites, both spatially and temporally, so as to generate hypotheses about the underlying mechanisms of spread and how it may be influenced by farm management practices and climatic factors such as rainfall.

The data presented here were collected and collated from two sites, the Mayuge farm and a field site at CORI (Block 36). At Block 36, the development of CWD on four *Coffea*

Phiri N. and Baker, P.S. (2009) *Coffee Wilt in Africa Final Technical Report*. CAB International.

Table 11.1: *Coffea canephora* plants exhibiting external symptoms of CWD in Block 36; (a) 2 January 2002, (b) 2 May 2004.

(a)

	Coffee clone	Plant number																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Block I	Is/2															X																		
	Is/6										X									X														
	Is/3				X									X			X																	X
	258										X			X																				
Block II	Is/2																															X		
	Is/3						X	X															X										X	
	258								X	X											X						X							
	Is/6																				X		X									X		
Block III	Is/2								X						X																			
	258								X																									
	Is/6					X			X																		X							
	Is/3		X																															

Continued

Table 11.1: Continued.

(b)

	Coffee clone	Plant number																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Block I	Is/2															X																		
	Is/6										X									X													
	Is/3				X									X			X																X
	258										X			X																			
Block II	Is/2																															X		
	Is/3						X	X															X										X	
	258								X	X											X							X						
	Is/6																				X		X									X		
Block III	Is/2								X						X																			
	258								X																									
	Is/6					X			X																		X							
	Is/3		X																															

X = coffee plant absent; shaded cell denotes coffee plant exhibiting external symptoms of CWD.

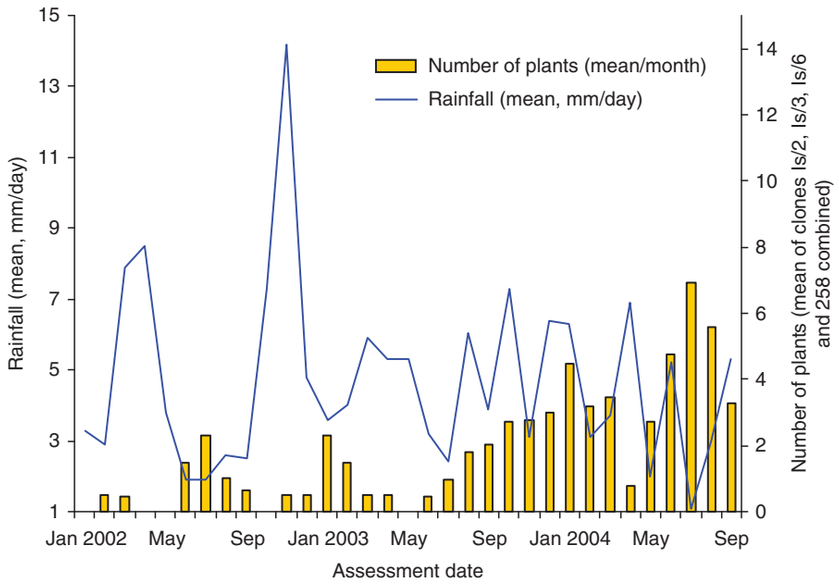
canephora clones known to be susceptible to CWD had been monitored since 2002. Block 36 was originally planted with 396 seedlings of clones Is/2, Is/3, Is/6 and 258, arranged in 12 rows of 33 plants, each clone planted as a single row in each of three blocks. Clones were randomly allocated to rows within each block as shown in Table 11.1. The number of plants exhibiting external symptoms of CWD was recorded monthly from January 2002, when several plants had already died due to CWD and been removed, to September 2004. The severity of symptoms on each plant was also recorded using the grading provided in Table 10.1. The data were analysed and used to generate graphical summaries, or disease 'maps', to help determine the rate and manner in which the disease has spread spatially and temporally. The data were also compared with the monthly data for rainfall and temperature recorded at CORI over the assessment period to determine if fluctuations in rainfall and temperature have any apparent influence on the CWD development.

In a similar manner, the severity of CWD on 130 mature coffee trees growing within a selected area in the Mayuge farm was assessed. At this site the trees were originally planted in such a way that the plants assessed more or less formed 26 rows of five trees, as presented in Figures 11.2 and 11.3. Trees were assessed for CWD during the period December 2003 to May 2004 and the data subjected to preliminary analysis, again by primarily producing graphical summaries. At both the Mayuge farm and Block 36, a number of plants were already exhibiting CWD symptoms when assessment commenced or had already been removed due to being killed by the disease.

11.4 Results

On 2 January 2002, only 9 of the 368 *C. canephora* present in Block 36 exhibited external symptoms of CWD (Table 11.1a). These were located at five focal points of the trial site, four of which were adjacent to points where a plant had already been removed due to the CWD symptoms being observed. Twenty-eight months later, on 2 May 2004, the

Figure 11.1: The development of CWD on *Coffea canephora* plants in Block 36 at CORI, Uganda, in terms of plants newly exhibiting symptoms, in relation to monthly rainfall.



number of symptomatic plants had risen to 166 (Table 11.1b),[1] with expanded areas of the disease being found adjacent to the original focal points. This represents an increase from 2.4 to 45.1% of those plants present or, on average, six plants per month. Clones 1s/2, 1s/3, 1s/6 and 258/24 showed some variation in the development of CWD, where the percentage of plants exhibiting symptoms of CWD increased from 3, 0, 3 and 1, respectively, to 76, 63, 72 and 54, respectively, during the assessment period.

As shown in Figure 11.1, the mean monthly rainfall at CORI fluctuated markedly during the assessment period, reaching a maximum of 14.2 mm in November 2002. Uganda has two rainy seasons, between about March and May and between about September and November. Rainfall is usually heavier and more prolonged during the former season. Some negative correlation was apparent between the number of coffee plants found to exhibit CWD symptoms for the first time (expressed as a mean for all four coffee clones) and the severity of rainfall, at least during the first 18 months of assessment, when the number of plants showing symptoms increased and reached a peak during the periods of low rainfall that followed the periods of high rainfall.

Possible explanations for this include:

1. The symptoms such as leaf yellowing and wilting become more recognizable during dry as opposed to wet periods, due to plants already being under greater water stress.

2. Increased rainfall (and hence relative humidity, for which data are not available) has caused an increase in the fungal activity in terms of infection and colonization of the host plant, for example, and led to an increase in damage to the plant and expression of symptoms. However, due to a lag period being required for symptoms to develop and become apparent, these are not recognizable until some weeks or months later.

It is also possible that the human activity increases at certain times, e.g. for weeding after rainy periods, which might in turn spread infection, but this requires further study.

There was no apparent effect of temperature on CWD development (not shown). However, temperatures do not fluctuate markedly in Uganda, with the average, minimum and maximum monthly means of 22.1, 19.9 and 27.3 °C, respectively, during the assessment period. Indeed, the monthly mean was between 19.9 and 24.2 °C for 27 of the 28 months.

Analysis of the data obtained over an 18-month period at the Mayuge on-farm site suggests that for the most part, and once the farm was affected by CWD, the disease did not appear to develop across the trial site in any particular direction as might be expected where the movement of water or soil is facilitating the dispersal of inoculum.

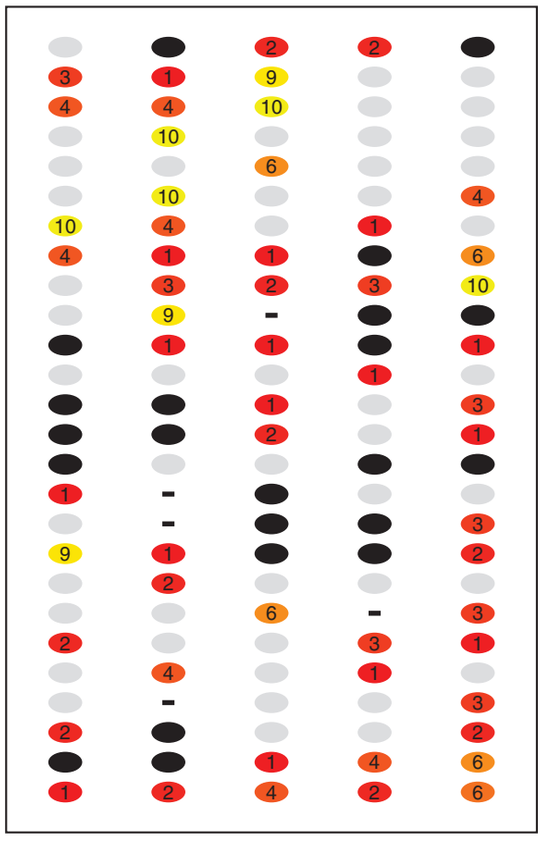
Instead, the disease seemed to spread outward from affected trees or clumps of affected trees (i.e. foci of infection) to adjacent trees that previously appeared disease-free. Observe, for example the top two rows of trees in Figure 11.2 where at the start there are only three trees infected. Over time, adjacent trees become infected and infection starts in row 3, but row 4 remains uninfected for about 500 days after the observations started. Figure 11.3 provides a summary of the second experiment.

[1] Tables 11.1a and 11.1b show the occurence and distribution of CWD at the beginning and end of the assessment period. Data for intermediate assessments are available but not presented.

Figure 11.2: The graphical summary showing the spatial layout of trees and the CWD development at an on-farm mapping site in Mayuge, Uganda. Figures refer to number of days elapsed at each observation.
The trial plot is depicted as a rectangle, each rectangle representing one of ten time points, or assessment visits. The headings give the day of each visit, the first (day 1) being on 20 December 2002 and the last (day 510) on 12 May 2004, and in brackets the number of the visit (1-10). Each coffee tree is shown as a coloured spot and shaded as white (missing), grey (no symptoms), yellow (denoting early symptoms severity with severity score 2 or 3), through orange (intermediate symptoms, severity scores 4 or 5) to red (severe symptoms, severity score 6). Trees that have died from CWD and been cut back are shaded black.

Although CWD symptoms did develop on some trees that were not adjacent to affected trees, these tended to be at the edge of the trial site and were perhaps affected by trees adjacent to the monitored area. While it is difficult to draw firm conclusions, the small number of such cases, coupled with the apparent tree-to-tree spread, suggests that the direct transfer of the pathogen on the machete is perhaps not the primary means of CWD spread. Machete wounding is possibly more important from the point of view of opening wounds for subsequent entry of the disease rather than direct physical

Figure 11.3: The graphical summary showing the spatial layout of trees and the CWD development at an on-farm mapping site in Mayuge, Uganda.
In this summary, the data for all ten time points are combined into one map, and it also highlights when the CWD symptoms were first observed. Missing trees are again shaded white, dead trees black and trees that remain uninfected throughout the set of visits in grey. However, trees shaded red through yellow started to exhibit symptoms (severity score 2 to 6) during the course of the study, those first developing symptoms in the earlier, intermediate and later visits shown in red, orange and yellow, respectively. The numbers in each spot states the visit at which symptoms were first noted.



transmission on the blade itself. Root-to-root transmission or localized movement of the pathogen in soil is also likely; disturbance of the soil with a hoe between trees, however, is a possibility that needs further study.

Subsequent analysis by Musoli *et al*. (2008) of another study plot provides statistical support for the visual impression of a gradual spread from tree to tree, with a statistically significant spatial correlation between trees with CWD. In the early stages of infection in the plot, the effective range of influence of an infected tree is up to two trees away, which rises to three trees by the end of the study period (6 years). This gives rise to the suggestion that once a tree begins to show infection, all trees within a three-tree radius (about 10 m) should also be grubbed up and destroyed.

11.5 Conclusions

These analyses have provided initial information on the rate and pattern of the CWD development at the two sites and have already proved useful in helping to determine how *Fusarium xylarioides* is being transmitted, what factors may influence disease development and, consequently, what measures may be taken to restrict or prevent the initial disease development and subsequent spread.

It is evident that the initial infection of the plot is essentially random, and we still have no idea how the fungus first enters the plot – though the most likely candidate is still by transfer of spores on the blade of an implement. However, once it has entered the plot the disease seems to spread to neighbouring trees, possibly aided by the actions of machete or hoe. It may, however, simply spread along roots and pass from one tree to another by itself; McRae (1924) reported that pigeonpea wilt (*F. udum*, the closest known relative to *F. xylarioides* (Chapter 4)) spreads about 3 m through the soil in one season, a not dissimilar velocity to that seen in the observations reported in this chapter.