



Impact of Coffee Wilt Disease (*Gibberella xylarioides*) on Regional Coffee Industry. A Review

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ABSTRACT

Coffee Wilt Disease has been a serious problem to the production of coffee in East Africa and other continents. In Ethiopia, annual national crop losses attributed to CWD was 3360 tone amounting to US\$3,750,976. In Uganda CWD was estimated to overall effect of about 50 percent lost of the revenue expected from coffee exports. In Tanzania, CWD resulted in a financial loss of US \$ 316,200 for over 10 years including US\$45,000 spent in eradication. In DRC, by the mid-1990s, 90% of plantations were affected. The disease was also found to spread through contaminated soil, running water and contaminated tools. Cultural management activities like slashing and digging should be avoided in CWD-prone coffee fields, and agronomic practices (pruning and stumping) that bring about wounding in coffee trees should be done with efficiently disinfected tools. Through an attempt to controle biologically, in the use of resistance variety, lines of Coffee arabica in Ethiopia showed differences in resistance to the CWD pathogen. In Uganda few CWD resistant Robusta clones were identified and released. In Tanzania use of copper based fungicides for stem painting to prevent landing of G. xylarioides spores.

1. INTRODUCTION

A coffee production is vital to the Ethiopian economy with about 25 million people directly or indirectly driving their livelihoods. They were engaged in production, processing and marketing of the crop in Ethiopia (CSA, 2016). Of the country's total production 95% comes from these small holder farmers. Ethiopia is the birthplace of Coffee Arabica and mostly produces *C. arabica*. It is number one source of export revenue generating about 25-30 percent of the country's total export earnings (Abu and Teddy, 2014).

Ethiopia remains the largest producer of coffee from 50 countries and fifth largest coffee producer in the world next to Brazil, Vietnam, Colombia, and Indonesia by contributing about 4.2 percent of total world coffee production.

In Uganda, more than 1.3 million households derive their livelihoods directly from coffee. The majority of them are rural smallholder farmers. Coffee contributes about 20 per cent of Uganda's foreign currency earnings (Ngabirano, 2012). In Tanzania, Coffee is second most important export, accounting for 23% of the country's total foreign exchange. In DRC

Coffee covering about 200,000 ha of which 85% is Robusta and 15% Arabica coffee (Phiri and Baker, 2009).

The importance coffee is under mined due challenge in abundance of Coffee wilt disease. Coffee Wilt Disease (*Tracheomyces*) is a systemic vascular disease caused by the fungal pathogen, *Gibberella xyloarioides* which causes a total death of infected coffee trees. It was first reported in 1927 on *C. liberica* var. *excelsa* in the Central African Republic (CAR, 1940). The disease has been a serious problem to the production of coffee in central and eastern Africa like DR Congo, Uganda, Tanzania and Ethiopia (Girma *et al.*, 2009). As CWD threatened the coffee industry throughout Africa, affected countries decided in 1956 to implement systematic elimination of all affected plants over large areas and to search for resistance both in wild and cultivated varieties (Flood, 2009). On *C. arabica*, it was observed first in Ethiopia by Stewart, (1957), who described the wilting symptom and also identified the causal organism to be *Fusarium oxysporum* f.sp *Coffeae* (Kranz and Mogk, 1973). It occurs in all of the coffee production systems to varying extent of damage among and within coffee fields and districts depending on different interacting factors (Girma, 2004). Coffee production (yield) at the farm level decreased by 37% and this led to a decline in income of 67%. The annual national crop losses attributed to CWD was 3360 tone amounting to US\$3,750,976 in Ethiopia (Flood, 2009).

In Uganda, Robusta coffee devastated by coffee wilt disease during the last two decades led to Losses of up to 45% (Kangire, 2013). In 1999, UCDA estimated that 14.5 million Robusta coffee trees (4.8% of the country's coffee stock) had been destroyed (Kangire, 2013). Over the period 1993–2003, CWD was estimated to have destroyed about 80,000 ha of Robusta, and caused losses of 1.2 million bags of coffee worth US\$100 million (UCDA, 2004). Robusta coffee trees were affected all over the country. As a result lost about 50 % of the revenue expected from coffee exports (Musebe *et al.*, 2009).

In Tanzania, Losses of Robusta trees can be equated to yield produced which is approximately 162,400 Kg of clean coffee lost due to killings of 54,200 by CWD. It is estimated that the disease has been causing a financial loss of approximately US \$ 316,200 for over 10 years including US\$45,000 spent in eradication (Kilambo *et al.*, 2010). In Democratic Republic of Congo, the CWD became widespread in Haut-Uele plantations and the entire surrounding territories. The incidence had reached 30%, mainly in the district of Haut-Uele (Kalonji-Mbuyi *et al.*, 1990)

Epidemiologically, infected plant parts such as stems, branches, leaves, roots, coffee husks and infected seedlings were the primary sources of new infection and spreading of the disease to new sites (Hakiza *et al.*, 2009). Coffee wilt disease management practices includes cultural control, biological control, use resistance variety and chemical controls are the major ones. Therefore, the objective of this paper is: to review the occurrence, distribution, impact and some major attempt done to overcome the challenges of coffee wilt disease (CWD) in coffee growing regions.

Impact of Coffee Wilt Disease (*Gibberella xyloarioides*) on Regional Coffee Industry.

Coffee production and its importance

Ethiopia's coffee production in marketing year of 2013/14 has marginally increased at a rate of 0.3 percent. In the current marketing, Ethiopia exported large volumes of coffee. However, the larger export volume failed to generate a proportionate increase in foreign exchange earnings as a result of a decline in international coffee prices (Abu and Teddy, 2014). Ethiopians remain heavy coffee drinkers, ranked as one of the largest coffee drinking countries in Africa. Nearly half of Ethiopia's coffee production is locally consumed.

In Uganda coffee is the most important cash crop, both in terms of employment and value of production. Uganda is the second African Robusta producer after the Ivory Coast (ICO, 2006). Uganda relies on two types of coffee, Robusta (*Coffea canephora* Pierre) and Arabica (*Coffea arabica* Linnaeus). Of these Robusta accounts 80–85 percent of the exports by volume and 65–80 percent of total earnings. However, Uganda has a higher competitive advantage for Robusta coffee production due to the fact that the country's general altitude is higher than 1000 m.a.s.l than that of most countries where the crop is grown. Thus, conferring exceptionally high consumer quality (Kangire, 2013).

Tanzanian coffee has an estimated area of 265,343 ha (TCB, 2006). Historically, in Tanzania a major predominance of Arabica over Robusta (Phiri and Baker, 2009). The major varieties of coffees grown in Tanzania constitute *Coffea arabica* and *Coffea canephora*. *Coffea arabica* is grown in the northern and southern highlands regions while *Coffea canephora* is grown in the western part, mainly Kagera region (Anon, 2009). However, this proportion seems to be changing over recent years. Robusta production is rising and Arabica falling. Currently about 80% of the coffee in Kagera is Robusta as a result of climate changing a shift from arabica to Robusta (Phiri and Baker, 2009). The main center for Robusta is the Kagera region, supporting about 250,000 coffee-growing families in districts of the north-western corner of Tanzania. In Tanzania, coffee contributes about \$ 117 million to export earning annually and provides employment to 420,000 families (Anon, 2009). According to Kilambo *et al.*, (2010) most smallholder farms produce about 250 kg/ha of clean coffee.

In DRC Coffee is a key cash crop. Smallholder farmers represent about 86% of total production with an average holding of 1.3 ha for Robusta and 0.8 ha for Arabica (Kalonji-Mbuyi *et al.*, 2009). Coffee in DRC has been in decline since the mid-1980s with the current coffee production some 80% below its peak, down to levels not seen since the 1940s. Since 2006/2007 season, production was 34,553 ton with 27,007 ton for Robusta and 7546 ton for Arabica , giving a national average clean coffee yield of 150–200 kg/ha for Robusta and 150–300 kg/ha for Arabica (Phiri and Baker, 2009).

History and geographic distribution of coffee wilt Disease

Coffee Wilt Disease (Tracheomycosis) is a systemic vascular disease caused by the fungal pathogen, *Gibberella xylarioides* which causes a total death of infected coffee trees. It was first reported in 1927 on *C. liberica* var. *excelsa* in the Central African Republic (CAR, 1940). The disease has been a serious problem to the production of coffee in central and eastern Africa like DR Congo, Uganda, Tanzania and Ethiopia (Rutherford, 2006; Flood, 2009; Girma *et al.*, 2009). As CWD threatened the coffee industry throughout Africa, affected countries decided in 1956 to implement systematic elimination of all affected plants over large areas and to search for resistance both in wild and cultivated varieties. Following this initiative, *C. canephora*-resistant varieties identified in DRC were used for replanting within DRC and Ivory Coast (Saccas, 1956). In 1986, new large-scale outbreaks of CWD were reported on *C. canephora* in the North East of DRC (Flood and Brayford, 1997a), from where it spread rapidly into Uganda, (1993) and North-West Tanzania, (1996). Because the disease appeared in these countries for the first time, there were no resistant varieties available for replanting in infected

areas and all available commercial varieties were susceptible to CWD. Since the 1990s killing hundreds of trees and the disease attacks all commercial coffee species including *Coffee arabica* and *Coffee canephora* at any growth stage (Flood, 2009; Girma *et al.*, 2009).

Historically, coffee wilt disease (CWD) on *Coffee Arabica* was first observed in Ethiopia (Keffa province) by Stewart, (1957), who described the wilting symptom and also identified the causal organism to be *Fusarium oxysporum f.sp Coffeae*. The causal was confirmed to be *Gibberella xylarioides* Heim and Saccas, of which *Fusarium xylarioides Steyaert* is the imperfect (conidial) state (Kranz and Mogk, 1973). Vander Graff and Pieters, (1978) reported that this pathogen caused a typical vascular wilt disease and was the main factor of coffee tree death in Ethiopia (Flood, 2009). It occurs in all of the coffee production systems of Ethiopia. Currently, the prevalence and importance of CWD have been markedly increasing throughout coffee producing areas of the country (Sihen *et al.*, 2012).

In Tanzania CWD was reported in 1997 in Misenyi District, Kagera region and since its appearance the disease has been demonstrated its ability to spread rapidly to new areas and cause serious losses on Robusta coffee.

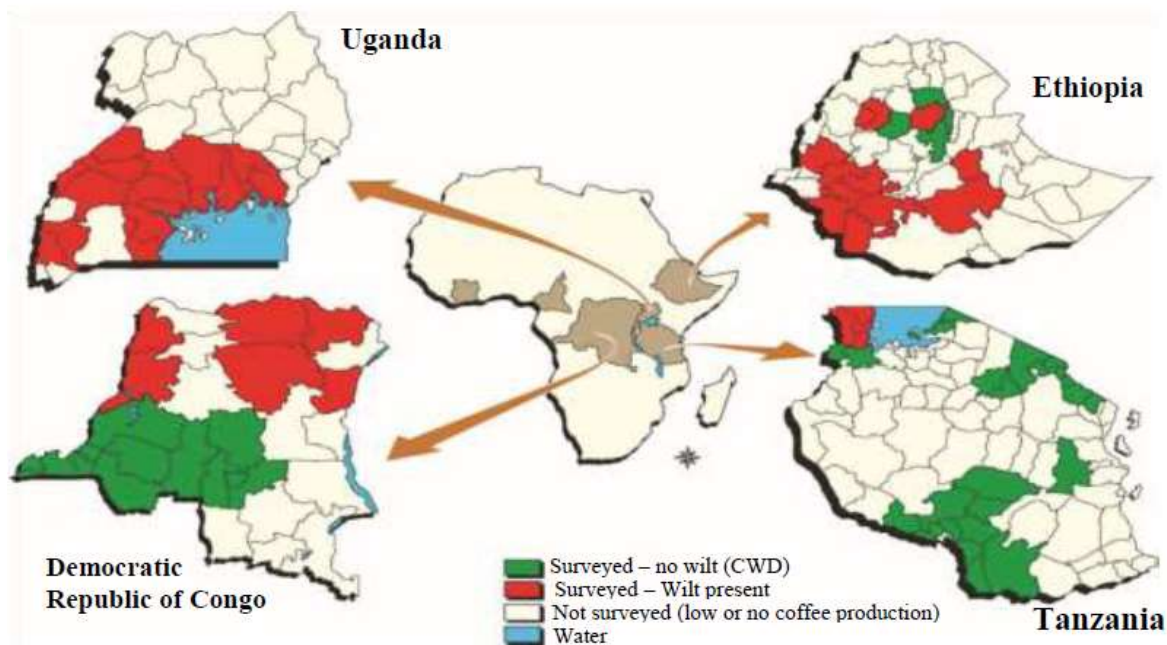


Figure 1. Current coffee wilts disease (CWD) distribution in Africa
Source:(Phiri and Baker, 2009).

Impact of Coffee Wilt Disease in Ethiopia

Coffee wilt disease was considered as a minor problem in Ethiopia and its impact therefore largely remained unnoticed. With CWD, the whole tree and neighboring all coffee trees die. CWD is a soil borne pathogen and this presents difficulties in the application of chemical treatments; affected fields may need to be left as fallow for some years or other crops planted (Girma, 2004). It occurs in all of the production

systems to varying extent of damage among and within coffee fields and districts depending on different interacting factors, mainly susceptibility of coffee trees, intensity of cultural practices and environmental conditions (CABI, 2003; Girma, 2004). Coffee production (yield) at the farm level decreased by 37% (from 1482 to 932 kg per sample farm), and this led to a decline in income of 67% (from 5038 to 1651 birr). The annual national crop losses attributed to CWD

was 3360 tone amounting to US\$3,750,976 in Ethiopia (Flood, 2009).

Impact of CWD in Ethiopian forest and semi-forest coffee plantation system

The occurrence of CWD was reported after assessment in four forest coffee areas in South-West and South East afro-montane rainforests with incidence of 0-16%, 0-10%, 0-6% and 0-30% in forest coffee areas of Harena, Bonga, Sheko and Yayu, respectively. The mean incidence varied between 2.4% at Sheko and 16.9% at Yayu (Arega, 2006). It was indicated that the damage was minimal in the dense stands of coffee (Merdassa, 1986). This was the first documented report that showed presence of CWD on forest coffee trees. Arega, (2006) also demonstrated that, the increasing occurrence of CWD in some forest areas like in Harenna (Bale) and Bonga (Keffa). The mean incidence in semi forest coffee ranged from 3.6% at Mettu to 15.5% at Gera situated in south west coffee-producing areas and the severity varied between 18.6% and 25.4% in some coffee fields at Yirgacheffe (Girma, 2004).

Impact of CWD in Ethiopian Garden coffee plantation system

Coffee wilt disease is prevalent in the southern region, specifically in the three major quality-coffee-producing

districts, namely, Wonago, Kochore and Yirgacheffe of Sidama and Gedeo zones. The highest incidence was at Yirgacheffe, followed by Kochore and Wonago. The severity of wilting in the sample fields of Yirgacheffe varied between 27.2% and 43.5% in the garden coffee as compared to that of the semi-forest coffee (Girma, 2004). In most coffee growing areas of SNNP region, the average incidence and severity was higher than in other regions. It was particularly high in the Sidama and Gedeo zones, with an incidence over 90% and severity of 25%. The incidence of CWD was also above 35% in garden coffee of West Gojam zone of Amhara regional state, but it was very low in Wolaita of Southern Nation, Nationalities and Peoples and West Hararghe of Oromiya (CABI, 2003). Coffee wilt diseases are more prevalent in plantation and garden coffee than forest and semi-forest coffee (Girma *et al.*, 2009; Sihen *et al.*, 2012). CWD was more prevalent in fields of garden production system like Harar and Bale area with severity range of between 27.2% and 43.5% which is high compared to that of the semi-forest coffee production system (Girma, 2004). The incidence of CWD was above 35% in garden coffee of West Gojam zone of Amhara regional state. This realizes that, there is a high variability among coffee produced in Oromiya region than other region which indicates the current state called Oromiya is true origin of coffee arabica.

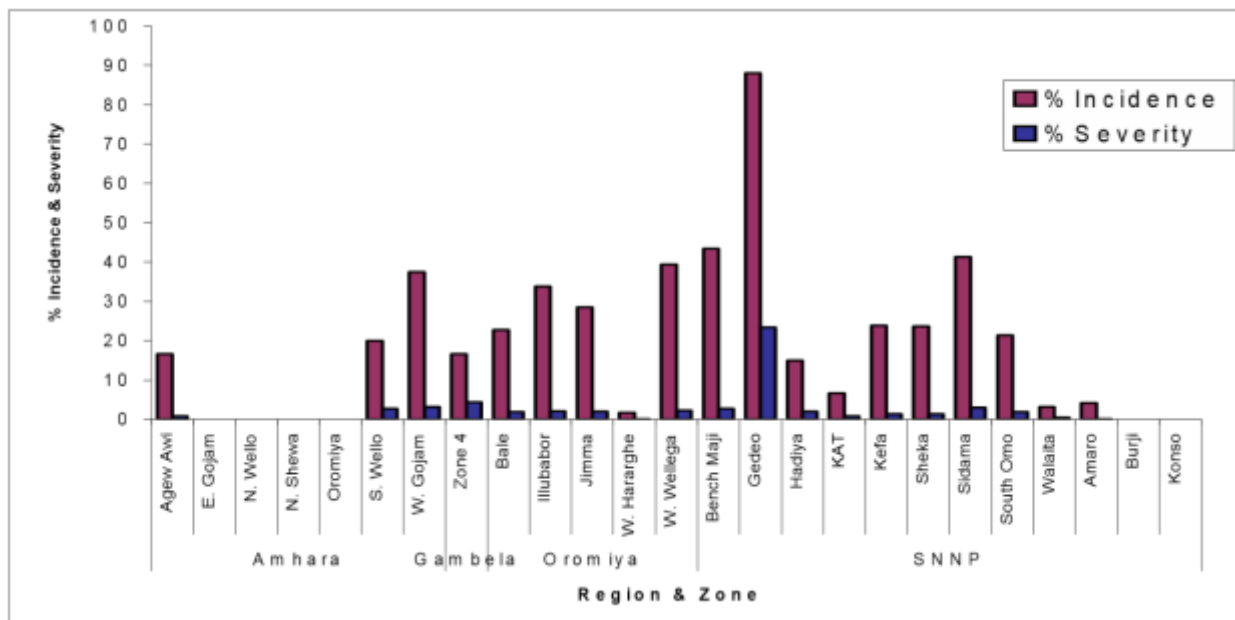


Figure 2. Incidence and severity of coffee wilt disease in different regions and zones of Ethiopia.

Source: (CABI, 2003).

Impact of CWD in Ethiopian coffee plantation system

Coffee wilt disease is commonly encountered in the research plots at Gera and Jimma amounting 42.5% and 48.2%, respectively. It is serious in the farmers' coffee plantations at the Gera, Chira and Gechi districts, with respective mean incidence ranging from 21.7% to 25.5%, from 32.3% to 77% and from 35% to 60%, respectively (Table 1). The overall mean coffee

tree loss in the farmers' plantation was more than 30% (Girma, 2004). The lowest percentage of the disease was recorded in the farmers' plantation at Tobba (17.3%), whereas the highest was at Bebeke (65.2%). Girma *et al.*, (2001) confirmed that the disease was more severe in plantation coffee at Bebeke, Tepi, Gera and Jimma. A remarkable increase in CWD severity of (11.5%) was recorded over a 6-month period in nine districts (woredas) of Gedeo and Sidama zones of Ethiopia (CABI, 2003). At Gemadro Coffee Plantation

Project of Ethio Agriseft alone, 91.2 ha of coffee were uprooted due to CWD. Coffee varieties 7454, 744 and Geisha were considered field susceptible. At Guraferda Woreda "Betework Alemu" private farm, out 340 ha planted with Geisha low land varieties, 200 ha was lost due to CWD (Belachew *et al.*, 2016). Limmu coffee plantation loss around 40 hectare of coffee farm annually due to CWD (LCP,

2012). According to current visit to Tepi and Bebeke coffee plantation, JARC staffs report indicate that, from 1997 planted Gesha (drought tolerant, high yielder and preferred low land released variety) at Baya farm number 4 of Tepi coffee plantation, out of 11 ha 4.1 ha was lost due to CWD (JARC, 2011; Belachew *et al.*, 2016).

Table 1. Incidence (%) of CWD plantation coffee under farmers' in south-west Ethiopia.

Location	Field	Estimated area (ha)	Incidence (%)	
			Range	Mean
Gera	Gicho 1	1.0	11.5–35.0	24.5
	Gicho 2	1.5	8.7–38.0	21.7
	Sedi-Loya	1.0	23.9–27.1	25.5
Chira	Gure-Genji	5.2	38.0–75.0	51.5
	Chira 1	4.5	55.0–89.0	77.0
	Chira 2	1.5	14.0–42.0	32.3
Tobba	Yachi	0.3	12.1–20.8	16.5
	Kilole	0.4	14.6–23.9	19.3
	Ageyu	0.2	8.3–27.0	16.1
Gomma	Shashamene	0.5	12.7–19.4	10.8
	Echemo	0.3	12.5–15.5	13.6
	Sombo	0.2	25.8–34.2	29.2
Gechi	Camp	0.5	25.0–70.0	48.9
	Mine-kobba	5.0	15.0–55.0	35.0
	Asendabo	5.0	37.7–78.6	59.7
Yayo	Jitto	1.0	11.0–34.0	22.5
Mettu	Sor	0.5	8.0–33.3	20.4
Mean	Total = 17	Total = 28.6 ha	8.3–89.0	30.9 ± 18.2

Source: (CABI, 2003) as cited by (Belachew *et al.*, 2016).

Impact of Coffee Wilt in Uganda

The devastation of Robusta coffee by coffee wilt disease (CWD) caused by the fungus, *Fusarium xylarioides Steyaert*, during the last two decades (1990s to late 2000s) led to Losses of up to 45 percent (Kangire, 2013). In 1999, UCDA estimated that 14.5 million Robusta coffee trees (4.8% of the country's coffee stock) had been destroyed based on estimates of partial information from 1996 survey conducted in ten districts (Kangire, 2013). Over the period 1993–2003, CWD was estimated to have destroyed about 80,000 ha of Robusta, and caused losses of 1.2 million bags of coffee worth US\$100 million (UCDA, 2004) greatly undermined government efforts to increase coffee production from 3.15 million bags in 2001/2 to 12 million bags by 2007/8 (Kangire, 2013). By 2002, CWD had affected at least 90 per cent of Robusta coffee farms and destroyed more than 45 per cent of Robusta coffee trees all over the country. The overall effect was a significant reduction in export volumes, from 4.2 million 60-kilo bags of green coffee beans exported in 1996 to 2.0 million bags in 2006 (Musebe *et al.*, 2009). This implies that Uganda could have lost about 50 percent of the revenue expected from coffee exports as a result of the disease (Musebe *et al.*, 2009). Many rural smallholder Robusta coffee farmers were left in abject poverty due to losses in coffee, leading them to change their lifestyles and reduce expenditure on their education, health and food consumption as well as social welfare (Musebe *et al.*, 2009). It also undermined previous research efforts

that had developed six high-yielding and good-quality Robusta coffee varieties, popularly known as clonal coffee (Kibirige-Sebunya *et al.*, 1996). These varieties may have been inadvertently selected for higher yields without considering their susceptibility to CWD (Kangire, 2013).

A research result which was carried out in Uganda on a Robusta coffee field experiment indicated that, the disease was found to spread from initial infections to healthy neighboring trees, resulting in an aggregated pattern (Musoli *et al.*, 2008). An infected tree could infect up to three healthy trees away, in any direction. Disease foci formed and expanded with time, coalescing but punctuated in spots planted with resistant hosts. The level of CWD was relatively high in percentage mortality at the beginning of the assessment in April 2001 (25.2%, Fig. 2a) and increased from 25.2% to 64.5% in March 2006 (Musoli *et al.*, 2008). The disease epidemic, as indicated by new mortalities, was highest between April 2001 and June 2002 but subsequently decreased and leveled off over time before finally reaching 0.4 %. Percentages of dead trees indicated that most hosts (clones) were affected to some degree by CWD in April 2001. The hosts showed tree mortalities ranged from 0% for J/1/1 and Q/3/4, to 54% for P/3/6. By March 2006, the percentage of tree mortality varied from 0% for J/1/1 to 96% for clone C/1/7 (Musoli *et al.*, 2008). The comparisons of clones on disease severity score gave approximately the same rankings as the comparisons on the percentage of tree mortality (Table 2).

Table 2. Model parameters describing the spread of coffee wilt disease

Clone	No of plants	First assessment: April 2001		Last assessment: March 2006	
		%Mortality	Disease severity Mark	%Mortality	Disease severity Mark
J/1/1	24	0a	1.00a	0.0a	1.00 a
Q/3/4	24	0a	1.00a	4.2b	1.25 a
R/1/4	24	11.1b	1.44abc	33.3c	2.67 bc
1S/3	18	12.5b	1.50abc	33.3c	2.33 b
B/2/1	24	29.2bc	2.25abcd	50.0cd	3.25 bcdef
Q/6/1	12	50d	3.00cd	50.0cd	3.00 bcd
C/6/1	24	12.5b	1.50abc	54.2cd	3.13 bcde
223/32	24	12.5b	1.63abc	58.3cde	3.37 bcdefg
L/2/7	24	12.5b	1.71abc	62.5def	3.50 bcdefg
Q/1/1	12	41.7cd	2.67abcd	66.7defg	3.67 bcdefg
B/1/1	24	29.2bc	2.17abcd	75.0defgh	4.00 cdefg
257/53	24	29.2bc	2.42abcd	83.3efgh	4.33 defg
G/3/7	24	25bc	2.13abcd	83.3efgh	4.42 defg
1S/2	24	4.2ab	1.17ab	87.5fgh	4.54 efg
E/3/2	24	20.8bc	2.08abcd	87.5fgh	4.50 defg
P/5/1	24	54.2d	3.33d	87.5fgh	4.50 defg
B/6/2	24	37.5cd	2.75bcd	91.7gh	4.79 fg
P/3/6	24	54.2d	3.46d	91.7gh	4.67 fg
H/4/1	18	27.8bc	2.61abcd	94.4gh	4.78 g
C/1/7	24	41.7cd	2.92cd	95.8h	

* Values with the same letter in a column are not significantly different according to Newman Keuls multiple range test ($P=0.05$)

Source: (Musoli *et al.*, 2008)

Survey results indicated that CWD was present in all 21 districts with 90% (range 53–100%) of farms infected. Mean severity was 44.5% (range 4–61% of trees). Each survey carried out in the interval of 6 months after the initial one. The rate of spread (tree-to-tree) was found to be relatively high with 8% of previously healthy farms. As a result national Robusta coffee production has fallen dramatically from 1997 to 2005 (Figure 3), which coincides with the spread of CWD. Even though, the economic and environmental

factors, the two species are somewhat different. It is evident that, Robusta production has suffered a substantial fall due to CWD. In contrast, Arabica production rose by 39% during the same period (Figure 3). Robusta coffee has declined by a cumulative total of US\$580 million over 1997 to 2007. This could be an underestimate since without CWD; Robusta production may have risen, as it has done in neighboring Tanzania (Figure 3) (Phiri and Baker, 2009).

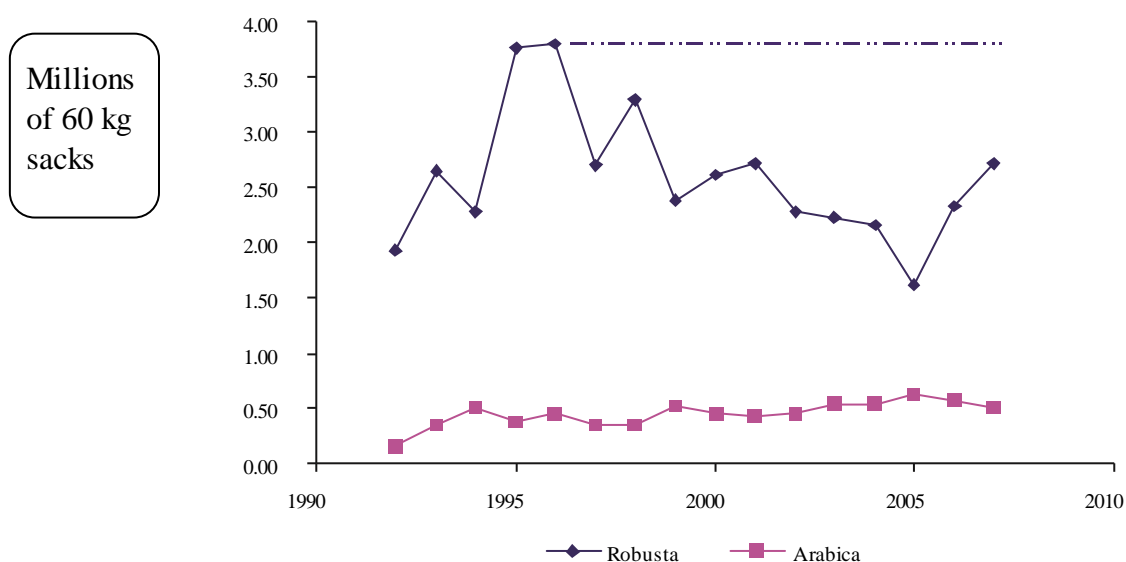


Figure 3. Total Ugandan coffee production since year 1992-2007

Source : (Phiri and Baker, 2009)

*Difference between the dotted line and actual production line from year 1996/97 is the decline in Robusta production that is attributable to coffee wilt disease (CWD).

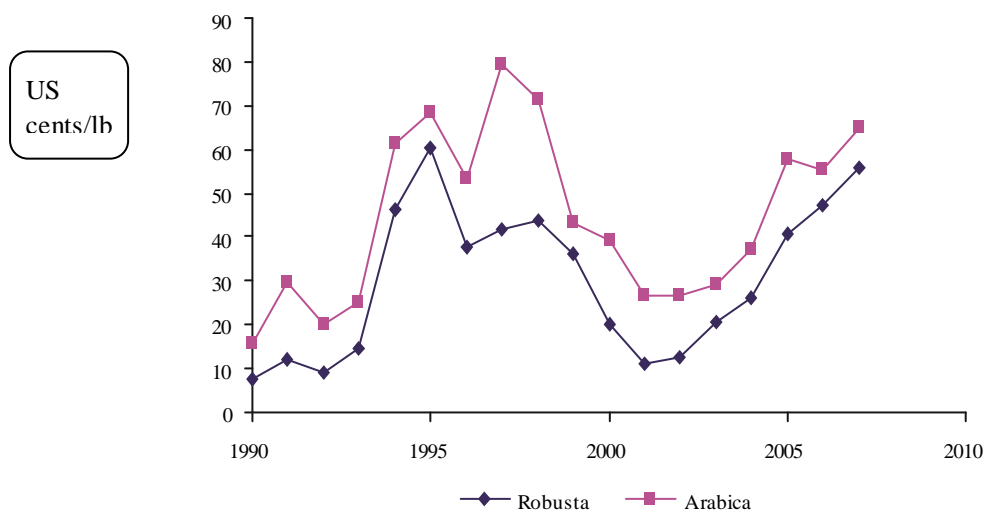


Figure 4. Coffee price paid to Ugandan growers.
Source : (Phiri and Baker, 2009)

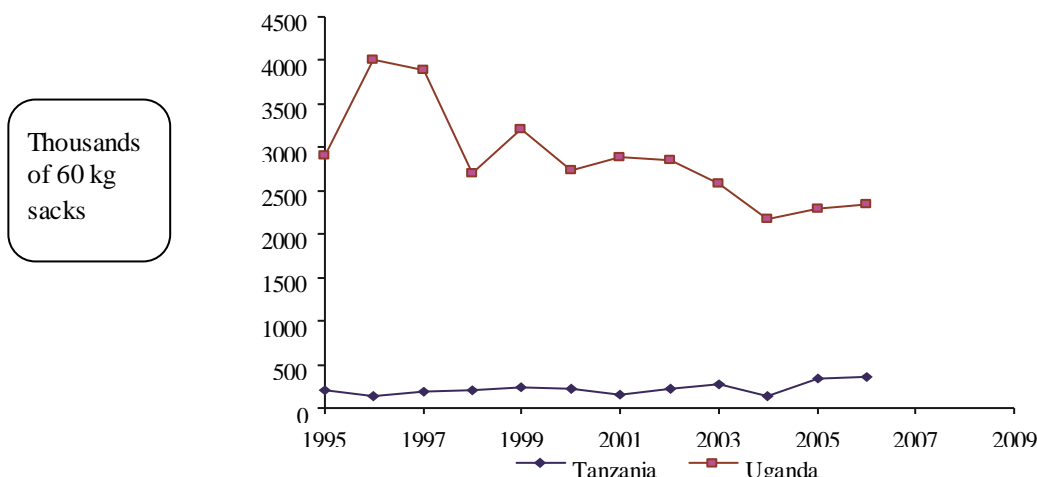


Figure 5. Robusta coffee production in Uganda and Tanzania since 1995 to 2007.
Source : (Phiri and Baker, 2009).

Impact of Coffee Wilt in Tanzania.

In Tanzania Robusta coffee is the major source of income to over 90% of households in Kagera. Since its appearance in Tanzania in 1997; coffee wilt disease (CWD) has clearly demonstrated its ability to spread rapidly to almost all Robusta growing areas in Kagera

Region. Losses of Robusta trees can be equated to yield produced which is approximately 162,400 Kg of clean coffee lost due to killings of 54,200 from CWD). It is estimated that the disease has been causing a financial loss of approximately US \$ 316,200 for over 10 years including US\$45,000 spent in eradication (Tables 3) (Kilambo *et al.*, 2010).

Table 1. Estimated coffee wilt disease (CWD) infected trees, yield losses ,cost of uprooting and uprooted (From Tanzania Coffee Research Institute Lyamungu, Moshi.).

District	Infected coffee trees 1997–2007	Estimated yield losses from CWD infected trees(kg) a	Yield losses in monetary terms (US\$)b	Cost of uprooting infected trees (US\$) c	Total losses (US\$)	Uprooted coffee trees	Percentage uprooted due to CWD
Bukoba	28,155	84,465	141,057	23,369	164,426	14,079	50
Misenyi	17,277	51,831	86,558	14,339	100,897	4,566	26
Karagwe	6,279	18,837	31,458	5,212	36,670	6,279	100a
Muleba	2,487	7,266	12,134	2,010	14,144	2,348	97
Total	54,200	162,399	271,207	44,930	316,137	27,272	50

a = Estimated that mature Robusta coffee tree of 25 years old can produce 3 kg of clean coffee. b= Estimated that the price of 1 kg clean coffee = US\$1.67 (October–December 2007 prices). c= Cost of uprooting a stump of infected Robusta tree = US\$0.83.

Source : (Phiri and Baker, 2009).

Impact of Coffee Wilt in Democratic Republic of Congo

The CWD disease then became widespread in Haut-Uele plantations, progressively spreading to all the surrounding territories. More plantations were abandoned and smallholders became increasingly distressed, as they saw their only source of income disappear. The incidence had reached 30%, mainly in the district of Haut-Uele (Kalonji-Mbuyi *et al.*, 1990). In Isiro, by the mid 1990s, 90% of plantations were affected, Mambasa 36%, Poko 34%, Bafwasende 28%, Opala 29% and Banalia 27 %, while Yangambi station was disease free. From Haut-Uele, the disease continued to spread down through a corridor of Robusta coffee that stretches from Mambasa to Irumu in the Ituri district. The incidence of infection in 1995 was estimated to range from 13 to 30% of trees in

plantations located in Mavivi, Mbawu and Mutwanga. In 1997, assessments indicated that the incidence exceeded 50% in Haut-Uele district (Kalonji-Mbuyi and Onyembe, 1996). More recently, CWD has infected plantations in the province of Equator through the district of Mongala on the border with the Oriental Province (Kalonji-Mbuyi, 2009). CWD is present in North Kivu, Oriental (Haut Uele and Tshopo). The approximate spread of infection is summarized in Figure 6 which is a compilation of all available survey data ranging back to 1987. CWD presents a very serious constraint to coffee production in DRC. The disease is widespread in the country and has destroyed many of the coffee plantations in the major production zones of the country. It seems very likely that the disease situation in DRC was much worse than during the historical outbreaks of the mid 20th century (Phiri and Baker, 2009).

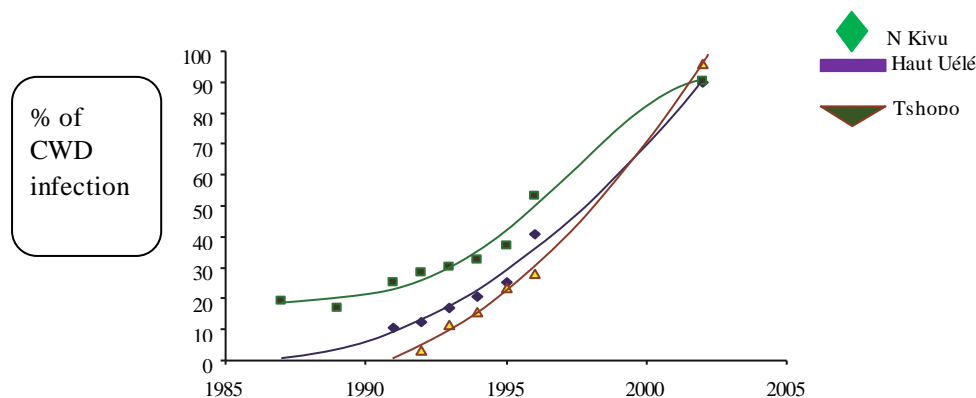


Figure 6. The spread of coffee wilt disease (CWD) infection in three provinces of DRC.

Source: (From Kalonji-Mbuyi, 2003) As cited by (Phiri and Baker, 2009)

Biology and epidemiology of the disease

Through research, it was established that infected plant parts such as stems, branches, leaves, roots, coffee husks and infected seedlings were the primary sources of new infection and spreading of the disease to new sites (Hakiza *et al.*, 2009). It was also found that, the pathogen did not survive for more than two years in infected dead plant parts and soil under field conditions. Besides infected plant parts, the disease were also found to spread through contaminated soil, running water and contaminated tools. All this information was utilized in the formulation and dissemination of cultural management strategies for controlling the disease (Kangire, 2013). The disease attacks plants at all stages of growth and infected plants show 100% mortality. Symptoms include wilting, defoliation and blue-black staining in the wood and under the bark (Flood, 1997). On a multi-stem coffee plant, the external symptoms occur sequentially until all stems or branches are killed. Coffee berries on affected plant ripen prematurely and dry up but remain attached to branches.

A study conducted in different Ethiopian forest since 2008-2010 indicate that, it is highly distributed in Ethiopia forest coffee (Getachew, 2017). In Uganda since 2002-2008 spatial distribution was studied. The age and density of plant was the case determining the

strength distribution of the coffee wilt Causal agent (Pinard *et al.*, 2016)

Coffee Wilt Disease Management Practices.

Cultural control.

Successful control of the disease depends on the principles of disease prevention (avoid wounding of any part of the plant) and phytosanitation. The conventional phytosanitary approach of uprooting and burning the whole infected coffee tree on the spot is strongly recommended to coffee farmers to maintain the disease as soon as symptoms are seen, but this relies on early diagnosis. Use of CWD-infected trees for any purpose is prohibited, and replanting with susceptible coffee seedlings should be delayed at least for 2 years (Girma, 2004; Hakiza *et al.*, 2009; Phiri and Baker, 2009). Cultural weed control activities like slashing and digging should be avoided in CWD-prone coffee fields, and agronomic practices (pruning and stumping) that bring about wounding in coffee trees should be done with efficiently disinfected tools (Kangire, 2013; Belachew *et al.*, 2016).

Biological control

Biological control has attracted great interest because of increasing regulation and restriction of fungicides or

unnecessary control attempts by other means. It is especially attractive for soil borne diseases because, it needs critical evaluation of economics of the country and the pathogens that are difficult to reach with specific fungicides (Montealegre *et al.*, 2003).

Use of CWD resistant cultivars as a result of Research achievements in coffee growing regions of Africa.

Vander Graff and Pieters, (1978) reported that coffee lines of *C. arabica* in Ethiopia showed differences in resistance to the CWD pathogen, thus providing potential for controlling CWD using resistant varieties in Arabica coffee. They suggested that resistance in *C. arabica* was quantitative in nature and horizontal, and there was no evidence of single gene (vertical) resistance that could be readily overcome by pathogen adaptation. Girma, (2004) reported that, there was a varietal differences in Arabica coffee. Being Ethiopia is known for its center of Coffee arabica, its genetic variability has a good opportunity to develop CWD resistant genotype in the country (Belachew *et al.*, 2015).

In Uganda, Arabica coffee was found to be totally resistant to the Xylarioides strain. But Robusta coffee was susceptible (Kangire, 2013; Musoli *et al.*, 2013). In addition to CWD resistant few lines were selected (Kilambo *et al.*, 2010).

Chemical control

In Tanzania use of copper based fungicides for stem painting to prevent landing of *G. xylarioides* spores. These approaches limits effective control of CWD as they are both expensive and use of copper based fungicides may lead to soils copper toxicity (Kilambo *et al.*, 2010).

SUMMARY AND CONCLUSIONS

Coffee production is vital to the Ethiopian economy with about 25 million peoples engaged in coffee economy. In Ugandan, more than 1.3 million households derive their livelihoods directly from coffee. Tanzania, Coffee export, accounts for 23% of the country's total foreign exchange and supporting about 250,000 coffee-growing families and provides employment to 420,000 families.

Coffee Wilt Disease (Tracheomyces) was first reported in 1927 on *C. liberica var. excelsa* in the Central African Republic. The disease has been a serious problem to the production of coffee growing regions. In Ethiopia annual national crop losses attributed to CWD was 3360 tone amounting to US\$3,750,976 in Ethiopia. In Uganda CWD was estimated to overall effect of about 50 percent lost of the revenue expected from coffee exports. In Tanzania CWD causes a financial loss of US \$ 316,200 for over 10 years including US\$45,000 spent in eradication. In DRC by the mid-1990s, 90% of plantations were affected. The incidence of infection in 1995 was estimated to range from 13 -50% of trees in plantations

located in different region of DRC. The pathogen did not survive for more than two years in infected dead plant parts and soil under field conditions. Besides infected plant parts, the disease were also found to spread through contaminated soil, running water and contaminated tools. All this information was utilized for cultural management strategies to control the disease. Biological control has a great interest because of restriction of fungicides or unnecessary control attempts by other means. Coffee lines of *C. arabica* in Ethiopia showed differences in resistance to the CWD pathogen due to resistance in *C. arabica* was quantitative in nature and horizontal. In Uganda, CWD resistant Robusta clones were identified and released. In Tanzania, copper based fungicides were used for stem painting to prevent landing of *G. xylarioides* spores.

In the future, Collection, characterization, Evaluation, adaptation and release of resistant variety to *Coffee wilt disease* should be implemented in coffee growing regions of the world; research centers and higher institutions should be involved in molecular breeding of CWD resistant varieties in coffee growing regions of Africa; better integrated control of Coffee wilt disease should be an opportunity for sustainable production and high revenue income for the regional countries and growers should be trained and aware to manage their coffee orchards in integrated disease management system.

Abbreviations used

CBAI	coffee bridge association international
CSA	Central statistics Authority
DRC	Democratic republic of Congo
FAO	Food and agricultural organization
ICO	International coffee organization
JARC	Jimma agricultural research Center
MY	Marketing year
TCB	Tanzanian coffee Board
UCDA	Uganda coffee development authority
TCDA	Tanzanian coffee development authority
%	percent
Kg	kilo gram
\$US	united state dollar

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