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The Statue and Management of Coffee Wilt Disease (Gibberella xylarioides) in Ethiopian Coffee Production

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Abstract
Coffee is directly or indirectly a source of livelihood for more than about 25 million people engaged in production, processing and marketing of the crop. Besides the crop is attacked by several diseases among which coffee berry disease, coffee wilt disease and coffee leaf rust caused by *Colletotrichum kahawae, Gibberella xylarioides* and *Hemileia vastatrix* respectively are the major fungal diseases contributing to reduced yield in the country. CWD (Gibbrela xylariodes) is prevalent in almost all coffee-growing regions, with national average incidence and severity of 28% and 5%, respectively.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. Coffee production (yield) at the farm level decreased due to CWD 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 (CABI, 2003). This economic loss coupled with difficulty to manage the disease indicates that CWD is the most difficult disease of coffee, in Ethiopia which needs more attention and the most distractive coffee production threat.
Keywords: Coffea arabica, coffee wilt disease, economic importance, Gibberella xylarioides

1. Introduction

Coffee has rapidly become one of the prominent commodity crops in global transactions, and it stands first in earning foreign currency for many countries including Ethiopia. Ethiopia has the longest tradition of coffee production and consumption in the world with a traditional way of cultivation and the performance of inimitable 'coffee ceremony'. Coffee is crucial to the Ethiopian economy because it contributes 10% of the country's gross domestic product and generates more than 40% foreign exchange earnings. Coffee remains crucial to the biological, social and economical values of the country, but despite being the birthplace of coffee, Ethiopia has not exploited and benefited from the crop to the best of its genetic and ecological potential. Coffee production systems remain predominantly traditional, and diseases and insect pests greatly reduce the productivity and quality of the produce.

Historically, coffee wilt disease (CWD) on *C. 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*. Later, based on comparative studies of the isolates collected from dying *Arabica coffee* trees from different origins and different *Coffea* spp., the causal was confirmed to be *Gibberella xylarioides* Heim & Saccas, of which *Fusarium xylarioides* Steyaert is the imperfect (conidial) state (Kranz and Mogk, 1973). Van der Graaff and Pieters (1978) reported that this pathogen caused a typical vascular wilt disease and was the main factor of coffee tree death in Ethiopia. During recent years, the prevalence and importance of CWD have been markedly increasing throughout coffee producing areas of the country (Girma, 2004; Oduor *et al*., 2005). This paper reviews the status of coffee wilt disease (CWD), including its occurrence, distribution and importance on *Arabica coffee* in Ethiopia, and highlights some of management options.

2. Importance of CWD in Ethiopia

For many decades, CWD was considered as a minor problem in Ethiopia, and its impact therefore largely remained unnoticed and its effect underestimated, but the losses incurred due to the disease are comparable to those caused by CBD. With CWD, the whole tree dies and all neighboring coffee trees die, so there is a loss of capital to the farmer; CBD affects only cherries and CBD can be controlled relatively easily with fungicidesbut 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). 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 (CABI, 2003). This economic loss coupled with difficulty to manage the disease indicates that CWD is the second important disease of coffee, after CBD.

3. Coffee Wilt Distribution in Ethiopia

Coffee production in Ethiopia is broadly grouped into four systems on the basis of biological diversity of the species and level of management, namely, forest, semi-forest, garden and plantation coffee (Meyer, 1965; Paulos and Demel, 2000). CWD occurs in all of the above coffee production systems to varying extent of damage among and within coffee fields and districts (Woredas) depending on different interacting factors, mainly susceptibility of coffee trees, intensity of cultural practices and environmental conditions (Merdassa, 1986; Girma and Hindorf, 2001; CABI, 2003; Girma, 2004).

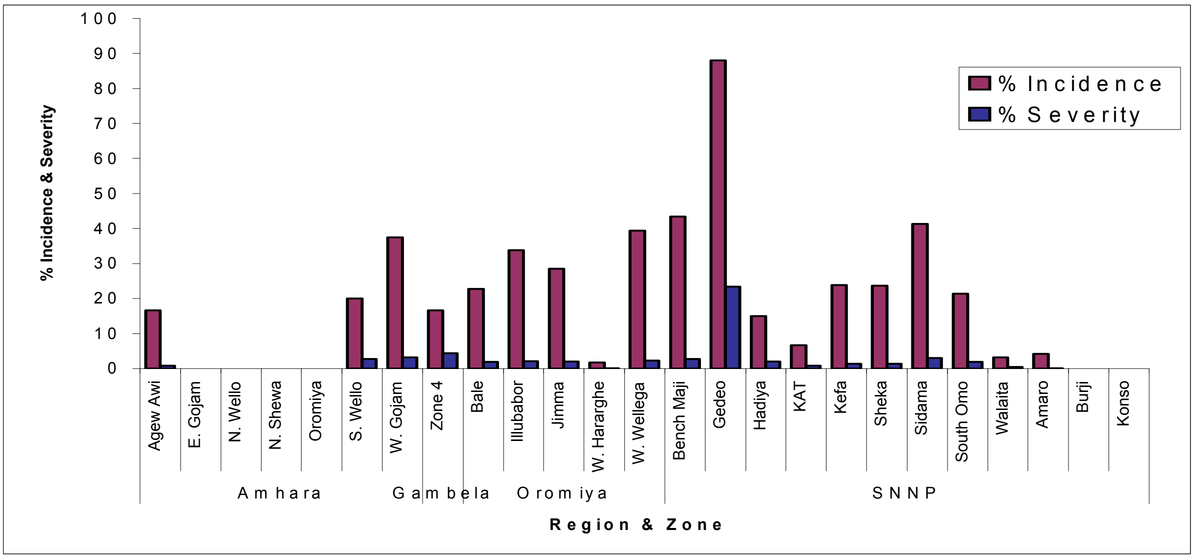

Figure 1: Incidence and Severity of coffee wilt disease in different regions and zones in Ethiopia
Source: - CABI (2003)

3.1. CWD in the forest and semi-forest coffee

The occurrence of CWD was reported after assessment in four forest coffee areas in south-west and south-east afromontane rainforests with incidence ranging between 5% at Sheko and 30% at Yayu. Although it was indicated that the damage was minimal in the dense stands of coffee (Van der Graaff, 1983; Merdassa, 1986), this was the first documented report that showed presence of CWD on forest coffee trees. Arega (2006) also demonstrated 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). A similar situation was observed in Bale, Jimma, Ilubabor, and West Wellega zones (CABI, 2003).

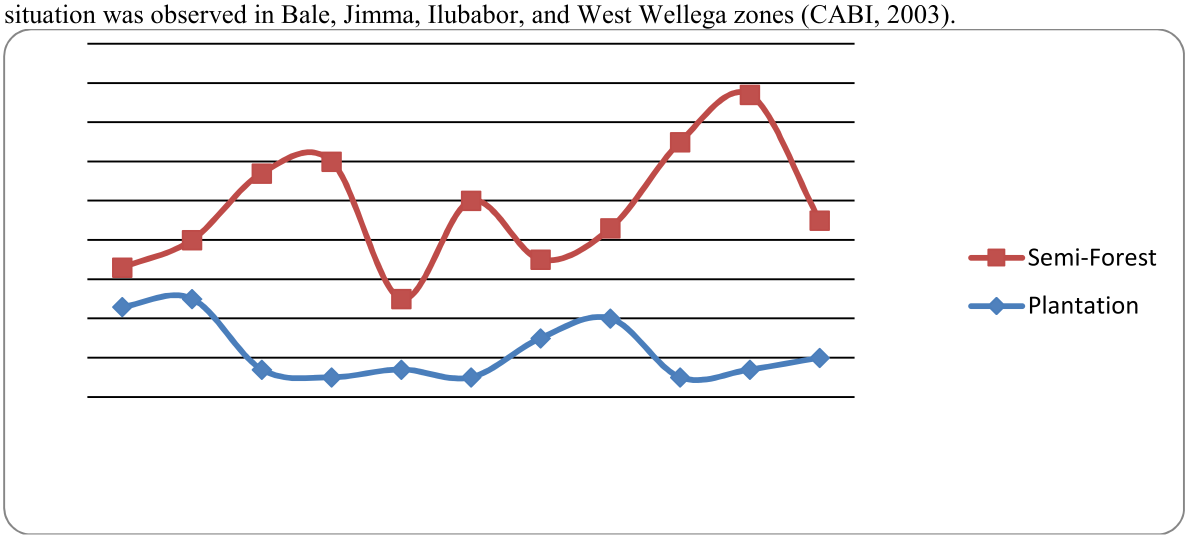

Figure 2. Incidence of CWD in the semi-forest and plantation coffee production systems

3.2. CWD in Garden Coffee

CWD 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, with highest incidence in Yirgacheffe followed by Kochore and Wonago. The severity of wilting in the sample fields in Yirgacheffe varied between 27.2% and 43.5% in the garden coffee as compared to that of the semi-forest coffee (Girma, 2004). Although the disease was not evenly distributed in most coffee-growing areas of Southern Nation, Nationalities and Peoples region, the average incidence (35%) and severity (5.0%) was significantly ($P < 0.001$) 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 (Southern Nation, Nationalities and Peoples) and West Harerghe (Oromiya) (CABI, 2003).

3.3. CWD in Plantation Coffee

The disease incidence is more severe in plantation coffee such as at research centers, on larger farmer holdings (1 to 5 ha) and in large estate commercial farms. CWD is commonly encountered in the research plots at Gera and Jimma amounting 42.5% and 48.2%, respectively (Fig. 1). 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 (Fig. 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 Bebeka (65.2%). Girma *et al*. (2001) confirmed that the disease was more severe in plantation coffee at Bebeka, Teppi, Gera and Jimma. Van der Graaff (1979) remarked that some spectacular failures of the modern plantations system could be due to *G. xylarioides*, and when comparisons are made across production systems, the disease is more destructive in garden and plantation coffees than in forest and semi-forest coffee systems.

The latter two systems are composed of heterogeneous coffee populations possessing varying levels of resistance and less human interference. However, in the former systems, characterized by relatively homogenous coffee trees and high levels of intervention, the disease spreads from tree to tree, from row to row and from one block to the other developing throughout the field (Girma, 2004). A remarkable increase in CWD severity of (11.5%) was recorded over a 6-month period in nine districts (weredas) of Gedeo and Sidama zones of Ethiopia (CABI, 2003). At Gemadro Coffee Plantation Project of Ethio Agr-iceft alone, 91.2 ha of coffee was up rooted due to CWD, coffee varieties 7454, 744 and Geisha were considered field susceptible, at Guraferda Woreda Betrework Alemu private farm out 340 ha planted with Geisha low land verities 200 ha was lost due to CWD (JARC, back to office report).

Limmu coffee plantation loss around 40 hectare of coffee farm annually due to CWD (LCP report, 2012). According to current visit to Tepi and Bebeka coffee plantation JARC staffs report indicate that, in 1997 planting of 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.

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

Location	**Field**	**Estimated area (ha)**	**Incidence (%) Range**	**Incidence (%) 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)

4. Coffee Wilt Disease Management Practices

4.1. Cultural control

Unlike with other coffee diseases, namely, CBD and CLR, coffee trees infected by CWD cannot be saved. 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 contain 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 *et al*., 2001; Girma, 2004).

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. Disinfection of farm implements such as machetes, bow saws and pruning shears with potent disinfectants (>75% alcohol) followed by intense heating with fire is strongly recommended to farmers whenever pruning, rejuvenating old coffee trees and thinning newly suckers. Farmers' field schools recommend growing cover crops such as *Desmodium* sp. and haricot bean, which are very efficient in suppressing weeds (so reducing the need for slashing) and as legumes, promote the growth of coffee trees. Applying ash, mulch and slashing between plots with hand weeding around coffee trees were also promising treatments in CWD control trials (CABI, 2005).

Figure 3. Uprooting and burning CWD infected trees (A), Use of infected trees for fire wood and house constraction (B & C)

4.2. Biological control

Biological control is the reduction of inoculums density or disease producing activities of a pathogen or parasite in its active or dormant state, by one or more organisms accomplishing naturally or through manipulation of the environment, host or antagonists, or by mass introduction of one or more antagonist (Baker and Cook, 1974). Biological control is the strategy for reducing disease incidence or severity by direct or indirect manipulation of microorganisms (Tesfaye and Kapoor, 2004). Antagonists that produce antibiotics kill pathogens and eradicate or control them from substrate. Some microorganisms occupy the niches and exclude pathogens from becoming established, thereby protecting plants from infection. 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). The result of a recent in vitro study conducted by (Muleta *et al*. 2007and Negash, 2011) on antagonistic effects of some rhizobacteria and Tricoderma isolates against the *F. xylarioides* were promising. Of 23 bacterial isolates obtained from rhizospheres of arabica coffee trees in south-west Ethiopia, 21 significantly inhibited the mycelial spread of *F.xylarioides. Bacillus subtilis*, designated as isolate 'AUBB20', was the most antagonistic to this pathogen. *T. viride* and *T.harzianum* has shown good potential in inhibiting the mycelial growth of *F. xylarioides*.

4.3. Use of CWD resistant cultivars

CWD destroyed coffee trees during the 1927s to the 1950s in African countries, particularly in Cameroon and Central African Republic and Ivory Coast. In contrast, several varieties of *C. Canephora* imported from the Democratic Republic of Congo (DRC) between 1914 and 1933 exhibited some level of field resistance, which was later confirmed through artificial inoculation (Muller, 1997). Muller, (1997) also reported apparent differences for the same materials planted in different areas of the region, i.e. certain *C. liberica* and *C. canephora* varieties showing resistance in Ivory Coast were completely susceptible in CAR, suggesting the resistance was either being influenced by environmental conditions or there were different physiological races of the pathogen in different localities of this region.

Van der Graaff 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.

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, 1997), 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.

Thus, following the successful use of resistance in Ivory Coast and the CAR, in Uganda, a breeding programme was initiated at the Coffee Research Centre (COREC) (now CORI) which aimed at developing resistant germplasm for managing the disease. Similar breeding programmes were initiated by TaCRI in Tanzania and the University of Kinshasa in DRC, Intra and interspecific differences among and between coffee species respectively provide potential genetic variability, which is exploited for resistance against CWD. Intraspecific variability is the best and easiest to exploit since resistant individuals are easily released as new varieties without undergoing hybridization, provided they posses other agronomic traits such as being high yielding; having resistance to other major diseases, mainly leaf rust and red blister disease and coffee berry disease and having good market qualities (Musoli *et al.*2009).

A breeding programme in Uganda resulted in screening of thousands of Robusta plants for resistance to CWD. The initial screening produced over 1,500 lines potentially resistant to the disease. Further screening and agronomic trials have reduced this to seven clones which have been officially released in Uganda (Phirii *et al.* 2010). Similar achievements were reported from Tanzania (Kilambo *et al.* 2010). Out of 875 lines 201 were found to resist CWD. Six clones were selected for multi-locations.

Girma *et al.* (2001) Girma and Hindorf, (2001) and Girma, (2004) reported varietal differences in Arabica coffee. Gambella origin accessions revealed significantly more wilt incidence as compared to French collections and Catimor lines. In the national coffee collection plots, SN5, F-35, and F-51/53 and 248/71 appeared to be highly susceptible with a 100% loss as compared to F-35 and F-51 conferring resistant reactions with significantly low death rates of 9.3 and 27.9% respectively. Chala *et al.* (2011) reported some released Sidama/Yirgachefe varieties like 971 (Fayate) and 974 (Odicha) shows high to moderate resistance with low death rates of 2.9 and 7.3% respectively. Generally it is difficult to comment with certainty on host resistance of such soil borne pathogen under field conditions, as there are a number of misleading factors; field resistance gives clue to select tolerant cultivars or lines that can be proved by seedling test under controlled environment. The experience from Uganda showed for clonal Robusta materials, that were presumed to be resistant during early years of outbreaks, were later found to be susceptible both in the field and seedling tests (Girma, 2004; CORI, 2001).

Artificial inoculation tests have shown that cultivars 1579, 200/71 and 8136 were resistant to CWD with low-percentage deaths (12.7%, 15.2% and 25.2%, respectively) accompanied by long incubation periods before symptoms appeared (Girma and Chala, 2008). Cultivars 146/71, 206/71 and 8144 showed moderate CWD infection, whereas others including Caturra and Geisha had the highest wilt severity (>90%) indicating susceptibility to the disease. There was a correlation between the lowest seedling death rates in the greenhouse and wilt severity observed in the fields. Thus, those cultivars demonstrating resistant reactions under both field and greenhouse conditions can be recommended for use in CWD-prone areas provided that they have other desirable traits like resistance to CBD, high yield and improved quality.

5. Conclusion

CWD, for many years remained as an endemic disease of *C. arabica* but has gained importance over time in almost all coffee-growing regions. The nationwide biological survey of CWD showed that on average, 27.9% of 1607 sample coffee farms were affected, with disease incidence ranging from 15% to 34.0% and disease severities varying between 1.3% and 5.0% (CABI, 2003; Oduor *et al.*, 2005). 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). 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 (CABI, 2003). This economic loss coupled with difficulty to manage the disease indicates that CWD is the second leading disease of coffee, after CBD in Ethiopia and the most distractive coffee production threat with out any solution till now.

The soil-borne nature of the pathogen and perennial character of coffee have made management of the disease difficult through the conventional control approach of ‘uproot and burn infected trees at the spot’. Avoidance of using infected trees for firewood, for construction of huts and fences or for other agricultural uses and avoidance of immediate replanting/replacing with susceptible coffee seedlings have been recommended (Girma *et al.*, 2001; Girma, 2004).

The longer-term prospects of successful management of CWD depend principally upon employing resistant coffee cultivars. In this regard, the genetic variability of arabica coffee populations presents a great opportunity to develop a number of CWD-resistant varieties. Some cultivars, such as 370, 1579, 200/71 and 8136, have shown resistance levels in artificial seedling inoculation tests that well correlated with that of natural infection in the field. To exploit the enormous genetic potential in the control of CWD, independent selection and screening program should be designed and implemented as experienced in the ever successful CBD programs.

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